Agent Evaluation Program

ESL-TR-89-307

FIRE EXTINGUISHING AGENTS, AQUEOUS FILM FORMING FOAM (AFFF) LIQUID CONCENTRATION PARTIAL PERCENTAGE

Subtask 3.01

FINAL REPORT

AUGUST 1989

AIR FORCE ENGINEERING AND SERVICES CENTER

AFESC

ENGINEERING & SERVICES LABORATORY
AIR FORCE ENGINEERING & SERVICES CENTER
TYNDALL AIR FORCE BASE, FLORIDA 32403

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PREFACE

This report was prepared by Applied Research Associates, Inc. under Contract Number F08635-88-C-0067 (Subtask 3.01), for the Engineering and Services Laboratory, Air Force Engineering and Services Center, Tyndall Air Force Base, Florida 32403.

Mr Richard N. Vickers was the Project Officer for AFESC/RDCF. This report presents the data taken during the AFFF testing completed between 1 June 1988 and 9 September 1988.

This test report has been reviewed and is approved.

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14. ABSTRACT

The objective of this test series was to qualify 3/4 and 1 percent Aqueous Film Forming Foam (AFFF) concentrate for use in Air Force fire fighting vehicles. Specific objectives were:

1. Determine the availability of AFFF in 3/4 and 1 percent concentrations from manufacturers on the Qualified Products List (QPL).
2. Evaluate 3/4 and 1 percent AFFF from each manufacturer in accordance with MIL-F-24385C test procedures and National Fire Protection Association (NFPA) Standard 412.
3. Determine the compatibility of the concentrates with existing Air Force fire fighting vehicles (P-2, P-4 and P-19). Demonstrate that these vehicles can adequately meter these fractional percentage concentrates.
4. Conduct a minimum of 12 large-scale (8,000 sq ft) JP-4 pool fire tests to compare the effectiveness of the reduced percentage AFFF concentrates with existing 3 percent concentrates.
5. Revise MIL-F-24385C to include production specifications for 3/4 and 1 percent AFFF concentrations.

15. SUBJECT TERMS

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SECTION I

INTRODUCTION

A. TEST OBJECTIVES

The objective of this test series was to qualify 3/4 and 1 percent Aqueous Film Forming Foam (AFFF) concentrate for use in Air Force Firefighting Vehicles.

Specific objectives were as follows:

1. Determine the availability of AFFF in 3/4 and 1 percent concentrations from manufacturers on the Qualified Products List (QPL).

2. Evaluate 3/4 and 1 percent AFFF from each manufacturer in accordance with MIL-F-24385C test procedures and National Fire Protection Association (NFPA) Standard 412.

3. Determine the compatibility of the concentrates with existing Air Force firefighting vehicles (P-2, P-4, and P-19). Demonstrate that these vehicles can adequately meter these fractional percentage concentrates.

4. Conduct a minimum of 12 large-scale (8,000 ft^2) JP-4 pool fire tests to compare the effectiveness of the reduced percentage AFFF concentrates with existing 3 percent concentrates.

Note: Large scale fire testing was deleted.

5. Revise MIL-F-24385C to include production specifications for 3/4 and 1 percent AFFF concentrations. This task will be completed after successful qualification of the fractional percentage concentrates.

B. MEASURES OF MERIT

1. To promote competition in future Air Force purchases, AFFF must be available from several U.S. manufacturers.

2. Successful AFFF concentrations must meet the minimum requirements of MIL-F-24385C and NFPA Standard 412.

3. Air Force firefighting vehicles must be able to meter fractional percentage AFFF within a range of minus 8 percent and plus 16 percent of the desired mixture ratio.

4. The 3/4 and 1 percent AFFF foams will be as effective as 3 and 6 percent foams in suppressing large JP-4 pool fires. Specifically, they will be capable of extinguishing 90 percent of the flames of an 8,000 ft^2 fire in 35 seconds or less and provide a surface seal that will suppress any burn back for a minimum of 14 minutes. These criteria are based on data collected by Jablonski (Reference) during an AFESC project to qualify 3 percent AFFF in 1980. They were derived by using the average of Jablonski's data, plus one standard deviation for the extinguishing time and minus one standard deviation for the burn back time.

5. The modification to MIL-F-24385C will be sufficient to permit the acquisition and regular use of 3/4 and 1 percent AFFF in standard Air Force firefighting vehicles.

C. BACKGROUND

Firefighting foams were introduced in the early 1900's; AFFF was developed much later. The first AFFF concentrates were formulated to be metered at 12 percent, that is, 100 gallons of agent would be composed of 12 gallons of AFFF to 88 gallons of water. Technology advances quickly permitted this ratio to be reduced to 6 percent. In 1980 the Air Force Engineering and Services Center/Engineering and Services Laboratory (ESL) qualified 3 percent AFFF. The 3 percent concentrate became the Air Force standard for firefighting vehicles. The U.S. Navy retained the 6 percent concentrate for its firefighting operations. Their cost/benefit analysis indicated that they would have to reduce the concentrate to 1 percent before it would be worth replacing all shipboard metering equipment. Pretest equipment evaluations and analysis indicate the feasibility of metering at 1 percent and possibly at 3/4 percent using the P-2, P-4, and P-19 firefighting vehicles.

The original goal of this project was to develop and qualify 1/4 and 1/2 percent concentrate AFFF agents. The foam manufacturers' response was that existing technology did not permit concentrates at these levels. One manufacturer did agree to provide 1/2 percent AFFF concentrate, but the cost would be prohibitive. Since all three manufacturers did agree to provide concentrates at the 3/4 and 1 percent levels, these were selected for further evaluation.

D. SCOPE

This project tested 3/4 and 1 percent AFFF concentrates for use in Air Force Crash Fire Rescue (CFR) vehicles. The use of the more concentrated AFFF will permit CFR vehicles to dispense more fire suppressant agent without AFFF resupply. There have been several military fires that were nearly under control, just as the foam concentrate supply was depleted. The fires then rekindled and became more intense while the firefighting vehicles were being replenished with additional agent. Firefighting vehicles with a more concentrated AFFF will result in a vastly increased firefighting capability. In addition, shipping and storage facilities and costs will be reduced significantly. The storage capacity of specially built splinter protection facilities and War Ready Material (WRM) kits will be increased substantially.

The feasibility of using 3/4 and 1 percent AFFF for routine Air Force firefighting operations was tested in accordance with MIL-F24385C and National Fire Protection Association (NFPA) Standard 412.

SECTION II
TEST DESCRIPTION

A. INTRODUCTION

This test program is divided into two parts, the firefighting vehicle compatibility and the AFFF qualification tests. Each test series is described in the following paragraphs.

B. TEST SITE

Tests were conducted at Fire Test Site #1, located at Tyndall AFB, Florida, approximately 7 miles southeast of the main gate and approximately 1.5 miles east of U.S. Highway 98 on Farmdale Road. Tyndall AFB is located on the Gulf Coast of Florida, about 10 miles southeast of Panama City, on U.S. Highway 98.

C. FIREFIGHTING VEHICLE PUMPING AND METERING TESTS

The P-2, P-4, and P-19 firefighting vehicles were calibrated and tested to determine their capability to meter and dispense an AFFF/water mixture in ratios of 3/4 and 1 percent AFFF to 99.25 and 99 percent water, respectively. This test series was conducted at the AFESC Fire Research Facility #1. Pumping and nozzle tests were completed in accordance with the requirements of National Fire Protection Agency Standard (NFPA) 412. Vehicles were calibrated in accordance with procedures contained in Annex 4 of the Test Plan, Firefighting Vehicle Fluid Calibration Procedures. A detailed description of this test series is contained in Appendix A.

D. MIL-F-24385C AFFF QUALIFICATION TESTS

A series of laboratory and small-scale fire performance tests were conducted to determine the physical properties of the concentrate and their fire suppression capabilities. This test series was conducted in accordance with MIL-F-24385C, Military Specification, Fire Extinguishing Agent, AFFF

Liquid Concentrate for Fresh and Sea Water, dated 12 March 1981. Foamability tests were conducted in accordance with NFPA 412.

These tests were conducted to qualify both the 3/4 and 1% AFFF concentrates produced by 3M, Ansul, and National Foam (NF). 3M supplied the same product for use at 3/4 and 1 percent mixing ratio. A total of five products were tested. All tests were conducted on the five products separately. In addition, to verify compatibility, 50/50 mixtures of the products of the three manufacturers were also tested.

Each test series was conducted using the fire test facilities of AFESC/RDCF and AFESC Fire Research Facility #1, Tyndall Air Force Base, Florida. Some specialized tests were conducted by the Naval Research Laboratory (NRL) in Washington, D.C. The tests conducted, and their associated MIL-F-24385C paragraph numbers are as follows:

NRL TESTS:

TEST	MIL-STD Ref Requirement	Paragraph Test
Refractive Index	3.3	4.7.1
Viscosity	3.3	4.7.2
pH Value	3.3	4.7.3
Spreading Coef.	3.3	4.7.4
Total Halides	3.3	4.7.8
Fluorine Content	3.3.4	4.7.16
Environment Impact	3.3	4.7.12
Precipitation	3.3.2	4.7.15

TYNDALL AFB TESTS:

TEST	MIL-STD Ref Requirement	Paragraph Test
General Corrosion	3.3	4.7.7
Localized Corrosion	3.3	4.7.8
Stability	3.3.2	4.7.10
Compatibility	3.3.3	4.7.11
Stratification	3.3.2	4.7.14
Film Formation and Sealability	3.3.1	4.7.6
28 ft^2 Fire Test	3.4	4.7.13
50 ft^2 Fire Test	3.4	4.7.13
Foamability	3.3	4.7.5
Dry Chemical Compatibility	3.3	4.7.9
Torque to Remove Cap Test	5.1.1.1.1(f)	4.7.17.2

1. General Corrosion Test - MIL-F-24385C Paragraph 4.7.7

The corrosion test series lasts 60 days. Tests were conducted in accordance with MIL-F-24385C, Paragraph 4.7.7.1. Specimens of G10100 steel, C70600 copper-nickel stainless steel, N04400 nickel-copper stainless steel, and C090500 bronze were immersed in separate 600 ml beakers filled with a mixture of each manufacturers concentrate and 10 percent sea water. Each metal specimen, except the bronze was milled to finished dimensions of 1/16 inch by 1/2 inch by 3 inches. The bronze was of the same dimensions as the other specimens except 3/16 inches thick and had sand cast faces. All specimens were degreased with acetone, rinsed with distilled water, and air dried. Each beaker was covered with a watch-glass to retard evaporation and let stand at room temperature for 60 days. Specimens were weighed before and after the immersion period and the weight loss calculated. The maximum allowable weight loss was calculated from the MIL-Spec criteria below.

CRITERIA:	Cold-rolled low carbon steel	- 1.5 milli-in/yr max.
	Copper-nickel (90-10)	- 1.0 milli-in/yr max.
	Nickel-copper (70-30)	- 1.0 milli-in/yr max.
	Bronze	- 100 milligrams max.

REF: MIL-F-24385C, Table I and ASTM E527

2. Localized Corrosion Test - MIL-F-24385C Paragraph 4.7.7

These tests also required 60 days to complete. All tests were conducted in accordance with MIL-F-24385C, Paragraph 4.7.7.2. Fifty specimens were placed in separate 600 ml beakers filled with a mixture of each manufacturer's concentrate and 10 percent sea water. Each beaker was covered with a watchglass to retard evaporation and left standing at room temperature for a period of 60 days. Daily inspections were conducted for evidence of pits. At the end of 60-days, all specimens were thoroughly examined.

CRITERIA: No Pits
REF: MIL-F-24385C, Table I

3. Stability Tests MIL-F-24385C Paragraph 4.7.10

Table 1 summarizes the test mixtures which were stored at $65^{o}C \pm 2^{o}C$ for 10 days. After the storage period, the one liter of fresh and sea water diluted samples were used for the stratification and precipitation tests. The AFFF/fresh water and AFFF/sea water mixtures were prepared at N and N/2 percent in sufficient quantities to perform the foamability, film formation, sealability, and the 28 ft^2 fire performance tests. One 28 ft^2 fire performance test was conducted with the premixed and stored fresh water mixture of each combination.

NOTE: N refers to the intended mixing ratio for each type agent, that is, for Type 3/4 N = 3/4% and for Type 1 N = 1%.

CRITERIA: Following the storage of the mixtures specified above, the combinations must pass the following tests:

Foamability	4.7.5
Film Formation and Sealability	4.7.6
28 ft^2 Fire Test	4.7.13
Stratification	4.7.14

TABLE 1. STABILITY TESTS HIGH TEMPERATURE STORAGE REQUIREMENTS

TYPE 3/4 AFFF:

MANUFACTURER	FULL STRENGTH 1 LITER	FRESH WATER 1 LITER	SEA WATER 1 LITER	FRESH WATER 3 1/2 GALLONS
3M	X	X	X	X
ANSUL	X	X	X	X
NF	X	X	X	X

NOTE: Water mixtures are mixed at N percent.

TYPE 1 AFFF:

MANUFACTURER	FULL STRENGTH 1 LITER	FRESH WATER 1 LITER	SEA WATER 1 LITER	FRESH WATER 3 1/2 GALLONS
3M	X	X	X	X
ANSUL	X	X	X	X
NF	X	X	X	X

NOTE: Water mixtures are mixed at N percent.

4. Compatibility Tests - MIL-F-24385C Paragraph 4.7.11

Compatibility tests were performed to ensure that samples from one manufacturer, when mixed with that of another manufacturer, retained their firefighting capability as specified by Military Specification MIL-F-24385C. Compatibility tests were conducted on 50/50 combinations of the agents from the three vendors. Table 2 summarizes agent combinations prepared and tested.

TABLE 2. COMPATIBILITY HIGH TEMPERATURE STORAGE REQUIREMENTS

TYPE 3/4 AFFF:

MANUFACTURER COMBINATIONS	FULL STRENGTH 1 LITER	FRESH WATER 1 LITER	SEA WATER 1 LITER	FRESH WATER 3 1/2 GALLONS
3M/ANSUL	X	X	X	X
ANSUL/NF	X	X	X	X
NF/3M	X	X	X	X

NOTE: All combinations were mixed 50/50 percent of each manufacturer.
NOTE: Water mixtures were mixed at N percent.

TYPE 1 AFFF:

MANUFACTURER COMBINATIONS	FULL STRENGTH 1 LITER	FRESH WATER 1 LITER	SEA WATER 1 LITER	FRESH WATER 3 1/2 GALLONS
3M/ANSUL	X	X	X	X
ANSUL/NF	X	X	X	X
NF/3M	X	X	X	X

NOTE: All combinations were mixed 50/50 percent of each manufacturer.
NOTE: Water mixtures were mixed at N percent.

After the storage period, the one liter fresh and sea water diluted samples were used for the stratification and precipitation tests. AFFF/sea water mixtures were prepared at N percent in sufficient quantities to perform the foamability an film formation and sealability tests. The 28 ft^2 fire performance tests were conducted with the premixed and stored fresh water mixture of each combination.

CRITERIA: Following storage of the mixtures specified above the combinations will pass the requirements of the following tests:

Foamability	4.7.5	
Film Formation & Sealability	4.7.6	
28 ft^2 Fire Test	4.7.13	test only the on-ratio mixtures (N%) for fresh and sea water
Stratification	4.7.14	
Precipitation	4.7.15	

5. Stratification Test - MIL-F-24385C Paragraph 4.7.10

AFFF/fresh and sea water solutions were mixed at N percent in lightly stoppered one liter glass cylinders and stored at $65^{o}C + 2^{o}C$ for 10 days. After the storage period, the sample solutions were examined for evidence of stratification.

CRITERIA: No visible evidence of stratification.

REF: MIL-F-24385C Paragraph 3.3.2(E) and 3.3.3(D)

6. Film Formation and Sealability Tests - MIL-F-24385C Paragraph 4.7.6

These tests were performed on all AFFF candidates and mixture ratios for fresh and sea water. The test fixture for this test series was a graduated 1000 milliliter cylinder, 5 inches high and 4 1/2 inches in diameter, and a 4 1/2 inch diameter wire mesh cone. For each AFFF candidate, 400 ml of water and 200 ml of 98 percent cyclohexane were placed into the graduated cylinder and covered by 200 ml of freshly made foam. The inverted wire mesh cone was pushed down into the cylinder, displacing most of the foam, but allowing the film-producing liquid to pass through the mesh to seal off the fuel. Residual foam was scooped from the cone to produce a foam-free, but sealed, surface. After a one-minute waiting period, a pilot flame was passed over the surface at a height of approximately 1/2 inch to determine if the AFFF adequately sealed the fuel, thereby preventing ignition.

7. Fire Performance Test, 28 ft^2 - MIL-F-24385C Paragraph 4.7.13

The purpose of the small scale fire tests was to determine if super-concentrate foams of 3/4 and 1 percent and 50/50 percent combinations of the foam concentrates from each manufacturer (to determine compatibility) were effective in fighting fuel fires.

The 28 ft^2 fire performance tests were conducted at the AFESC Fire Test Facility #1. A mild steel fire test pan, six feet in diameter and four inches deep, was used for these tests. A series of 43 fires were performed. The AFFF premix was applied at a rate of 2 gallons/minute for 90 seconds.

After the AFFF fractional foam was applied, a 1 foot diameter pan, with gasoline as a fuel, was ignited and placed in the center of the larger pan. Once the fuel in the test pan was reignited, the 1 foot diameter pan was removed. The burn back rate was measured for each fractional percentage foam. Dry chemical compatibility tests were also conducted in conjunction with the 28 ft^2 fire performance tests.

Ten gallons of gasoline were burned for each 28 ft^2 fire test. Fuel handling safety procedures are contained in Annex 7 of the test plan. Detailed test procedures are contained in Annex 5 of the Test Plan, Fire Performance Tests, 28 ft^2 and 50 ft^2.

A separate fire test was conducted for each of the following conditions, with the qualification criteria indicated:

CRITERIA:	MIXING RATIO		
	N/2 F&S	N F&S	5N S Only
Maximum time to extinguish (sec.):	45	30	55
Minimum burn back time (sec.):	300	360	200

NOTE: N refers to the intended mixing ratio for each type agent, that is, for Type 3/4 N = 3/4% and for Type 1 N = 1%.

F = Fresh Water S = Sea Water

REF: MIL-F-24385C, Table II

8. Fire Performance Test, 50 ft^2 - MIL-F-24385C Paragraph 4.7.13

The 50 ft^2 fire performance tests were conducted to determine the rate of fire extinguishing at 10-second intervals from the beginning of the foam application time, as well as the total extinguishing and burn back times. These tests were also conducted at the AFESC Fire Research Facility #1. A mild steel test pan, 8 feet in diameter and 4 inches deep, was used for these tests. These tests were conducted using AFFF mixtures of N percent and sea water only. Six fires were performed to complete this series. Fifteen gallons of gasoline were used during each test. Fuel handling safety procedures are contained in Annex 7 of the test plan.

Burn back rates and areas were measured for each fractional percentage foam. Data were hand-recorded on the data forms supplied in Annex 5 of the Test Plan. Video tape recordings and color photographs were taken periodically.

Detailed test procedures are contained in Annex 5 of the test plan, Fire Performance Tests, 28 ft^2 and 50 ft^2.

CRITERIA: For 50 ft^2 fire test only a sea water mixture of N% was tested.

Maximum time to extinguish (sec.): 50

Minimum burn back time (sec.): 360

40-Second Summation, minimum: 320

REF: MIL-F-24385C, Table II

9. Foamability Tests - MIL-F-24385C Paragraph 4.7.5

These tests were conducted on all AFFF specimens for mixtures of N% fresh and sea water in accordance with the specified paragraph of MIL-F-24385C and NFPA Standard 412, Method A. These tests were conducted in conjunction with the 28 ft^2 Fire Performance Tests. At the completion of the foam application for the fire test a small portion of the foam was sprayed on the foam sample collector and collected in a standard 1000 ml graduated cylinder. Once the foam container was completely filled, foam application was discontinued and the timing of the 25 percent drainage started, excess foam was struck from the top of the container with a straight edge and the container was wiped clean. The total weight of the foam sample was determined to the nearest gram by subtracting the weight of the empty container from that of the full container. The weight of the foam in grams was divided by four to obtain the 25 percent drainage volume in milliliters. At 30 second intervals, the level of accumulated solution in the cylinder was recorded. The drainage time versus the volume relationship was recorded until the 25 percent volume was exceeded. The 25 percent drainage time was interpolated from the data.

CRITERIA: Foam expansion minimum - 5:1
Foam drainage 3.3 minutes minimum

REF: MIL-F-24385C, Table I, NFPA Standard 412

10. Dry Chemical Compatibility Test - MIL-F-24385C Paragraph 4.7.9

These tests were conducted during a 28 ft^2 fire test using a foam mixture of N percent with sea water. Six of the 28 ft^2 fires included the dry chemical compatibility test. After the 90-second foam application and before placing the burning pan in the test burn pan, 1 pound of potassium bicarbonate dry chemical, conforming to O-D-1407, was sprinkled evenly over the foam blanket using a sieve on a long handle. This was accomplished so that the time from the end of foam application to placing the burning 1 ft^2 pan into the test burn pan did not exceed 90 seconds.

CRITERIA: Minimum burn back time - 360 seconds

REF: MIL-F-24385C, Table I

11. Torque to Remove Cap Test - MIL-F-24385C Paragraphs 4.7.17.2 and 5.1.1.1.1(f)

The pour opening caps on all 5 gallon containers used during the test series were checked with a torque wrench to determine the torque required to remove the caps.

CRITERIA: Torque not to exceed 50 inch/pounds

SECTION III
TEST RESULTS

A. GENERAL

The AFFF agent specimens from the three different manufacturers of both 3/4 and 1 percent were tested to determine compliance with MIL-24385C. Most of the required tests were conducted at Tyndall AFB, Florida. with the remaining tests conducted at the Naval Research laboratory (NRL). Only the Tyndall test results are reported in this document. Results of the NRL tests are reported in a separated report by NRL.

B. TYNDALL TESTS

1. General Corrosion Tests.

The General Corrosion tests were conducted between June 9, 1988 and August 7, 1988. These tests were conducted in accordance with MIL-F-24385C, Paragraph 4.7.7.1 and the test procedures described in Section II of this report. To determine the maximum permissible weight loss for these tests the test criteria specified for the steel and stainless steels specimens in the MIL-SPEC in milli-inches per year maximum was converted to grams/60 days maximum weight loss (the period of the corrosion test) as follows: All corrosion specimens were machined to dimensions of 3 inches by 0.5 inches by

weight and dimensions. The dimensions were reduced on all six sides by the allowable corrosion rate specified in MIL-F-24385C in milli-inches/year divided by 6 to obtain milli-inches/60 days. The volume and allowable final weight was recalculated. The initial weight minus the allowable final weight being the allowable weight loss in 60 days. The table shows the figures used and the results obtained. The permissible weight loss for the 60-day test period for each specimen type is shown in the last column of Table 3.

Table 3. Partial Percentage AFFF Corrosion Calculations

SPECIMENS		LENGTH (inch)	WIDTH (inch)	THICKNESS (inch)	VOLUME (cu in)	WEIGHT (grams)	DENSITY (gr/cu in)	MAX. CORR. /YEAR (inch)	MAX. CORR. /60 DAY (inch)	WT* (grams)	WT LOSS MAX 60 DAYS (grams)
STEEL	G10100	3.00	0.50	0.0625	0.0938	11.74	125.23	0.0015	0.000250	11.63	0.1075
STAINLESS	C7060	3.00	0.50	0.0625	0.0938	12.62	134.61	0.0010	0.000167	12.54	0.0771
STAINLESS	N0440	3.00	0.50	0.0625	0.0938	12.40	132.27	0.0010	0.000167	12.32	0.0757
BRONZE	C90500	3.00	0.50	0.1875	0.2813	38.76	137.81	0.1 gr			0.1000

WT* = Weight after 60 days at a maximum corrosion rate of X milli-inches per year.

WEIGHT LOSS MAX 60 DAYS = Maximum weight loss for the test specimens.

All tested specimens passed the corrosion tests except National Foam 3/4 and 1 percent solutions with Steel UNS G10100 specimens and Ansul 3/4 and 1 percent solutions with Copper-Nickel stainless steel C 70600 specimens. These Agent/specimen combinations will be retested under a follow-on test program. See Appendix D for complete test data.

REF: MIL-F-24385C, Table I

CRITERIA: Cold-rolled low carbon steel - 1.5 milli-in/yr max.
Copper-nickel (90-10) - 1.0 milli-in/yr max.
Nickel-copper (70-30) - 1.0 milli-in/yr max.
Bronze - 100 milligrams max.

2. Localized Corrosion Tests.

These tests were conducted between June 10, 1988 and August 8, 1988 in accordance with MIL-F-24385C, Paragraph 4.7.7.2 and the test procedures described in Section II of this report. At the completion of the 60-day test period all specimens were thoroughly examined. There was no evidence of any pitting detected. All agents passed this test.

REF: MIL-F-24385C, Table I

CRITERIA: No pitting of the specimens.

3. Stability tests.

Stability tests were conducted in accordance with MIL-24385C, paragraph 4.7.10 to evaluate AFFF performance after an extended storage period. Samples of each agent were stored at 65°C ± 2°C for 10 days to accelerate the aging process. After the storage period, the following tests were performed using the aged agents:

Foamability	4.7.5
Film Formation and Sealability	4.7.6
28 ft^2 Fire Test	4.7.13
Stratification	4.7.14

Tests were completed on both agent samples that had been stored at the elevated temperature and some that had not. No significant differences in the test results were noted. Tests results for the individual tests are included in the associated paragraphs for the particular tests listed above.

REF: MIL-F-24385C, paragraph 3.3.2

CRITERIA: Pass each individual test (See individual test results)

4. Compatibility Tests.

These tests were conducted in accordance with applicable paragraphs of MIL-24385C. Following the prescribed storage period, the 50/50 combinations of the three manufacturer's agents were tested with the following results:

a. Foamability tests. All agent combinations tested exceeded the minimum expansion ratio of 5:1 except Ansul/3M 3/4 percent with seawater, Ansul/National 3/4 percent seawater, and National/3M 1 percent seawater with expansion ratios of 4.20:1, 4.76:1, and 4.50:1, respectively.

All agent combinations failed the 25 percent minimum foam drainage time requirement of 3 minutes 20 seconds, with drainage times ranging from 1:37 to 3:03 minutes. However, these combination agents did not perform significantly different than the separate agents.

b. Film Formation and Sealability Tests. All agents combinations passed the film formation and sealability test, with no sustained ignition.

c. Fire Performance Tests, 28 ft^2. All agent combinations exceeded the maximum 30-second extinguishment time with times ranging from 33 to 72 seconds. All agent combinations passed the 25 percent minimum burnback time of 6 minutes. These agent combinations did not perform significantly different than the individual agents.

d. Dry chemical Compatibility Tests. Dry chemical compatibility testing was performed in accordance with MIL-24385C. All agent combinations passed this test with minimum 25 percent burn back times exceeding the 360-second requirement, except the Ansul/National 1 percent fresh water mixture, which had a 25 percent burn back time of 334 seconds. These burnback times are not significantly different form the individual agent burnback times with dry chemicals. Complete test results are contained in Appendix B.

e. Stratification Tests. Following the 10-day storage requirement, a visual examination of the samples contained in the cylinders was performed, with no evidence of stratification.

REF: MIL-F-24385C, Paragraph 3.3.3
NFPA 412, Test Method A, Paragraph 4.3.2.1 & Table 3-1

CRITERIA: Foam expansion minimum - 5:1
Foam drainage 25% - 3.3 minutes minimum
Film formation and sealability - No sustained ignition
28 ft^2 fire test performance
extinguishment time - 30 seconds
25% burn back - 360 seconds
Stratification - No evidence

5. Stratification Tests.

Following the 10-day storage requirement, a visual examination of the individual agent samples contained in the cylinders was performed, with no evidence of stratification.

REF: MIL-F-24385C, Paragraph 3.3.2

CRITERIA: No visible evidence of stratification

6. Film Formation and Sealability tests.

Film Formation and Sealability tests were conducted in conjunction with 28 ft^2 fire test on individual foam specimens mixed with fresh water at N percent. All agents passed the film formation and sealability test, with no sustained ignition. Complete test data are contained in Appendix B.

REF: MIL-F-24385C, Paragraph 3.3.1

CRITERIA: No sustained ignition

7. 28 ft^2 Fire Performance Tests.

All agents mixed at N/2 exceeded the required extinguishment time of 45 seconds, except National Foam 1% agent mixed with sea water, which produced an extinguishment time of 42 seconds. The remaining agent's extinguishment times ranged from 62 seconds to no extinguishment.

Agents mixed at N percent exceeded the required extinguishment time of 30 seconds, except National Foam 1% mixed with fresh water which produced an extinguishment time of 29 seconds. The remaining agent's extinguishment times ranged from 39 to 70 seconds.

Agents mixed at 5N percent passed the required extinguishment time of 55 seconds, with extinguishment times from 34 to 45 seconds.

Burn back tests results were as follows:

All agents passed the burn back test requirement listed in the table below by resealing, except 3M 0.75% fresh water mixture with 234 seconds and National 1% fresh water mixture with 251 seconds burn back time. Complete test results are contained in Appendix B.

REF: MIL-F-24385C, Paragraph 4.7.13

CRITERIA:

	MIXTURE RATIO		
	N/2 F&S	N F&S	5N S Only
Maximum time to extinguishment (sec.):	45	30	55
Minimum Burn Back Time (sec.):	300	360	200

8. 50 ft^2 Fire Performance Test

As prescribed by MIL-24385C, the 50 ft^2 fire performance tests were conducted with agents mixed at N% with seawater only. Test criteria are listed above. All agents tested failed the required extinguishment time. Extinguishment times ranged from 63 to 86 seconds to no extinguishment. Burn back rates were measured on all agents tested with the percentages of fire area extinguished at 10, 20, 30, and 40 second summation values. All agents failed to meet the summation value, ranging from 105 to 220 seconds. Complete test results are contained in Appendix C.

REF: MIL-F-24385C, Table II

CRITERIA: Maximum time to extinguish: 50 seconds
Minimum burn back time: 360 seconds
Minimum 40 second summation: 320 seconds

9. Foamability Tests

Foamability was measured in conjunction with 28 ft^2 fire test on all agents mixed at N% with fresh and sea water. All agents exceeded the minimum expansion ratio requirement of 5:1, and failed the 25% foam drainage time of 3.3 minutes except National 0.75% fresh water mixture with a 3:50 drainage time. Complete test results are contained in Appendix B.

REF: NFPA 412, Test Method A, Paragraph 4.3.2.1 & Table 3-1

CRITERIA: Foam expansion minimum - 5:1
Foam drainage 25% - 3.3 minutes minimum

10. Dry Chemical Compatibility Tests

Dry chemical compatibility testing was performed in conjunction with the 28 ft^2 fire performance tests for agents mixed at N percent with seawater only. All agents passed this test with burn back times exceeding the 360-second requirement. Complete test results are contained in Appendix B.

REF: MIL-F-24385C, Paragraph 3.3 & Table I

CRITERIA: Minimum burnback time: 360 seconds

11. Cap Removal Torque Test

The torque required to remove the pour opening caps on all five gallon containers of agents tested did not exceed 50 inch pounds.

REF: MIL-F-24385C, Paragraph 5.1.1.1.1 (f)

CRITERIA: Torque not to exceed 50 inch pounds

C. NRL TEST RESULTS

The results of these tests are reported under a separate cover.

SECTION IV

SUMMARY AND CONCLUSIONS

While candidate AFFF agents passed most of the individual tests prescribed in MIL-24385C, the fire performance of all except one agent was below minimum standards. The agents from two of the three agents tested failed the corrosion tests.

Due the generally substandard performance of the 3/4 and 1 percent candidate agents, it was decided to conduct parallel tests on the Air Force standard 3 percent AFFF as a comparison. There was no significant difference between the test results of the 3 percent AFFF and the partial percentage AFFF candidates. Test results for the 3 percent tests are included in Appendix B, along with the partial percentage test results.

The test specifications presented in MIL-24385C allow considerable variation in test conditions and as a result do not yield consistent results. A revised MIL-specification is due out soon from NRL, MIL-24385D, which will provide for more rigorous test conditions and agent application procedures. Consequently, this test series will be repeated under a follow-on subtask in accordance with MIL-24385D. The large-scale fire tests were also curtailed until after the completion of the follow-on MIL-24385D testing.

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APPENDIX A

FIREFIGHTING VEHICLE PUMPING AND METERING TESTS

APPENDIX A

FIREFIGHTING VEHICLE PUMPING AND METERING TESTS

A. EXPERIMENTAL PROCEDURES

A simple experimental approach was used to evaluate the foam metering systems on the P-2, P-4, and P-19 crash rescue vehicles. First, the fluid depths in each tank were measured to determine how much water and foam concentrate were used each time agent was discharged from the roof turret. In the cases of the P-2 and P-4 vehicles, the turret was operated at several different settings of the foam metering valve. In the case of the P-19, the turret was operated for several different sized orifice holes. In each instance a curve was generated relating mixture ratio versus valve setting or orifice area.

The first step in this process required "calibrating" the tanks on each vehicle. This was done by setting the vehicle on level ground and filling each tank to capacity. Next, fluid depths were measured in each tank. Then, 100 gallons of water were drained from the water tank and the resulting depth was recorded. The process was repeated until the tank was empty. The resulting data were plotted at Figure A-1. This curve also shows how much water is remaining in the tank of a P-19 for a given depth of fluid. This process was repeated for the foam tank by draining 10 gallons of foam during each increment. Figure A-2 shows the resulting curve for a P-19 foam tank.

Care was taken to estimate fluid depths to the nearest sixteenth of an inch. The dipstick was rocked slightly to obtain the minimum depth reading which would correspond to the case where the stick is vertical. Depth measurements were made at the same location in the tank each time. Meniscus was ignored since it is present in all readings, and its effect will cancel.

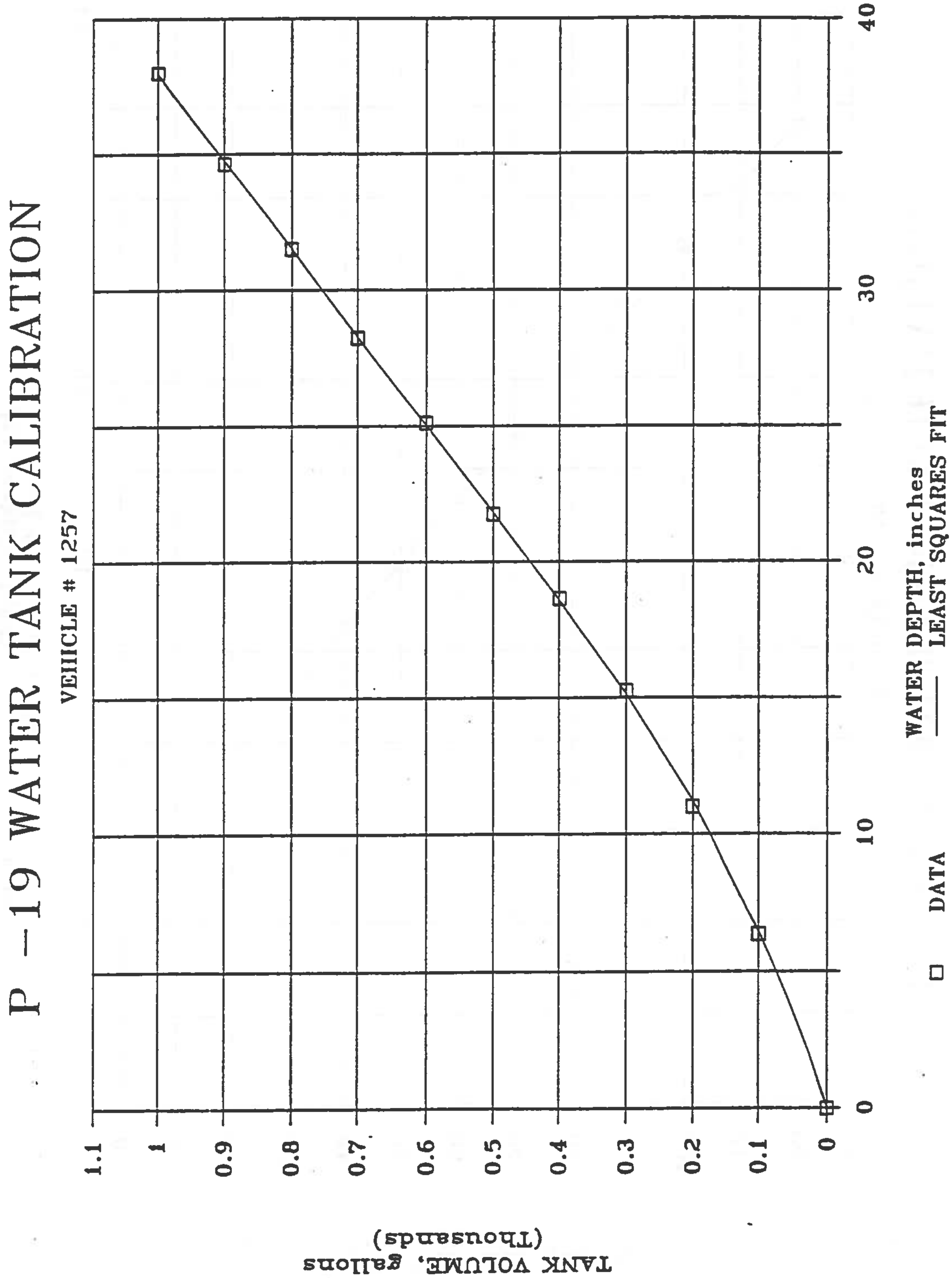

Figure A-1. P-19 Water Tank Calibration

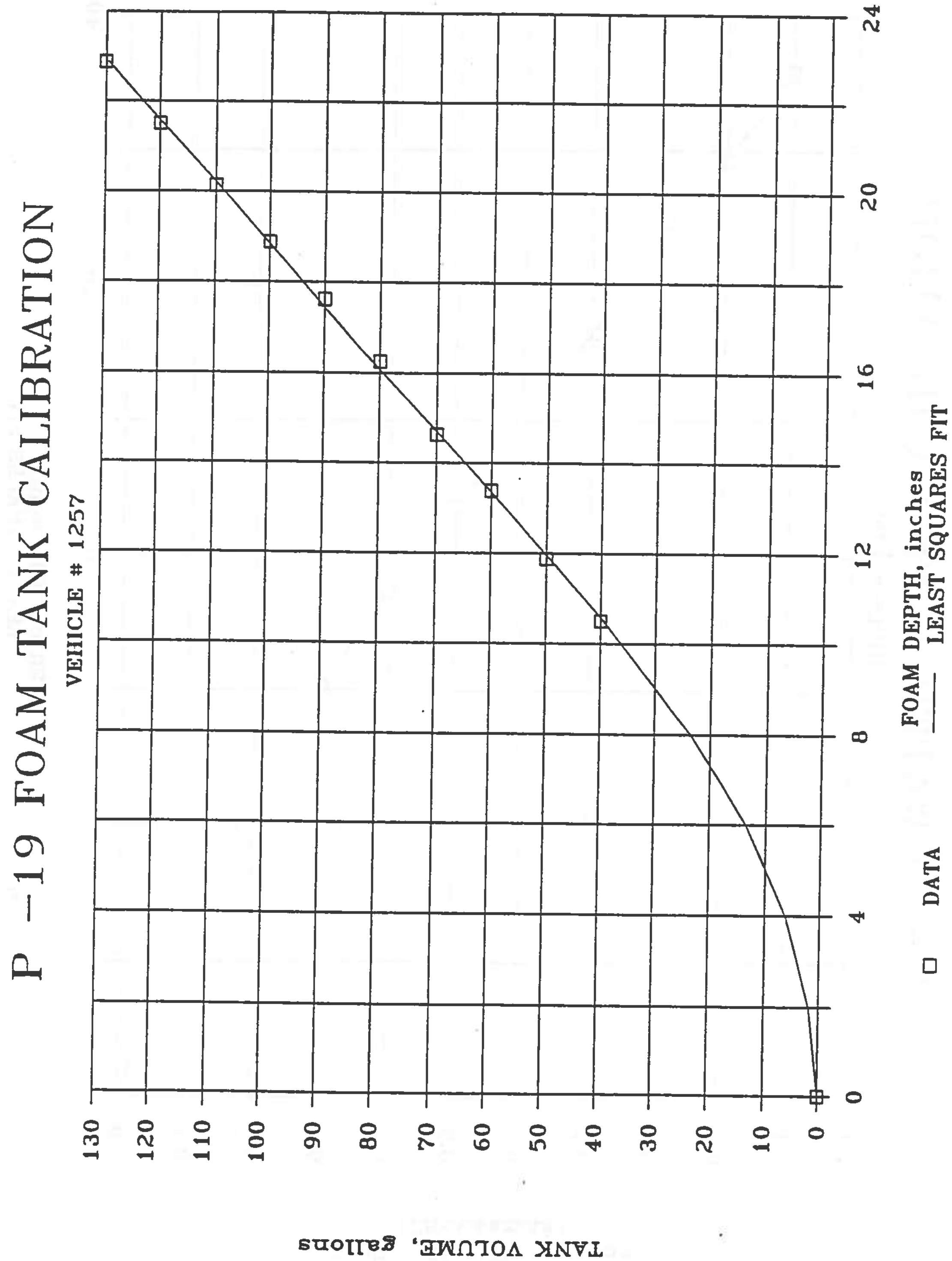

Figure A-2. P-19 Foam Tank Calibration

Curves were fit to the data to speed reductions of metering and flow data and to provide an estimate of measurement roundoff error. The cross sections of the upper portions of the tanks are nearly constant thus permitting the data to be fit using a linear least squares fit. A polynomial fit had to be used to fit data for the lower portion of the tank.

Five vehicles were calibrated; Figures A-1 through A-10 show the resulting calibration curves. Table A-1 summarizes the analytic fits to the calibration data. The solid lines in each figure represent the fits. Table A-2 shows the magnitude of the roundoff error. This error was estimated by computing the average absolute variance between the data and the least squares fit. The cross section of the tanks will vary slightly due to the presence of baffles, etc. Therefore, the estimates should be a little high.

The calibration data for the vehicles were then obtained by operating the roof turret for different foam valve settings and measuring the resulting foam and water used at each setting. These data could then be converted to the mixture ratio which is ratio of foam volume to total agent discharged.

B. P-19 CRASH RESCUE VEHICLE

1. Description

The P-19 is the newest of the three vehicles tested in this program. It also uses a unique around-the-pump metering system. Figure A-11 is a schematic of the system. In operation, water and diluted foam concentrate are drawn into the pump where they are mixed. Most of the agent is discharged out the nozzle. Some of the mixture is routed back around the pump through an eductor where foam concentrate is drawn into the system. A pressure regulating valve maintains the pump discharge pressure at 200 psig. This arrangement effectively separates the metering system into two systems -- a foam loop

TABLE A-1. FOAM AND WATER TANK CALIBRATION EQUATION

VEHICLE TYPE	SERIAL NUMBER	FOAM EQUATION	WATER EQUATION
P-19	1225	$V=7.276\,D-36.96,\ D\geq10.5$ $V=.353\,D^2+.235D,\ D<10.5$	$V=30.92\,D-173.8,\ D\geq18.63$ $V=.501\,D^2+12.26D,\ D<18.63$
P-19	1257	$V=7.375\,D-39.55,\ D\geq10.75$ $V=.342\,D^2+.017D,\ D<10.75$	$V=31.08\,D-189,\ D\geq18.88$ $V=.531\,D^2+11.06D,\ D<18.88$
P-2	L389	$V=9.9\,D-14.33,\ D>4.375$	$V=51.61\,D+516.4$
P-4	L383	$V=7.208\,D$	$V=38.705\,D$
P-4	L368	$V=7.051\,D$	$V=38.705\,D$

TABLE A-2. ESTIMATED ROUNDOFF ERROR

VEHICLE TYPE	SERIAL NUMBER	AVERAGE ROUNDOFF ERROR FOAM gallons	WATER gallons
P-19	1225	.8	2.32
P-19	1257	.68	3.62
P-2	L389	.46	10.53
P-4	L383	1.14	4.03
P-4	L368	1.06	7.05

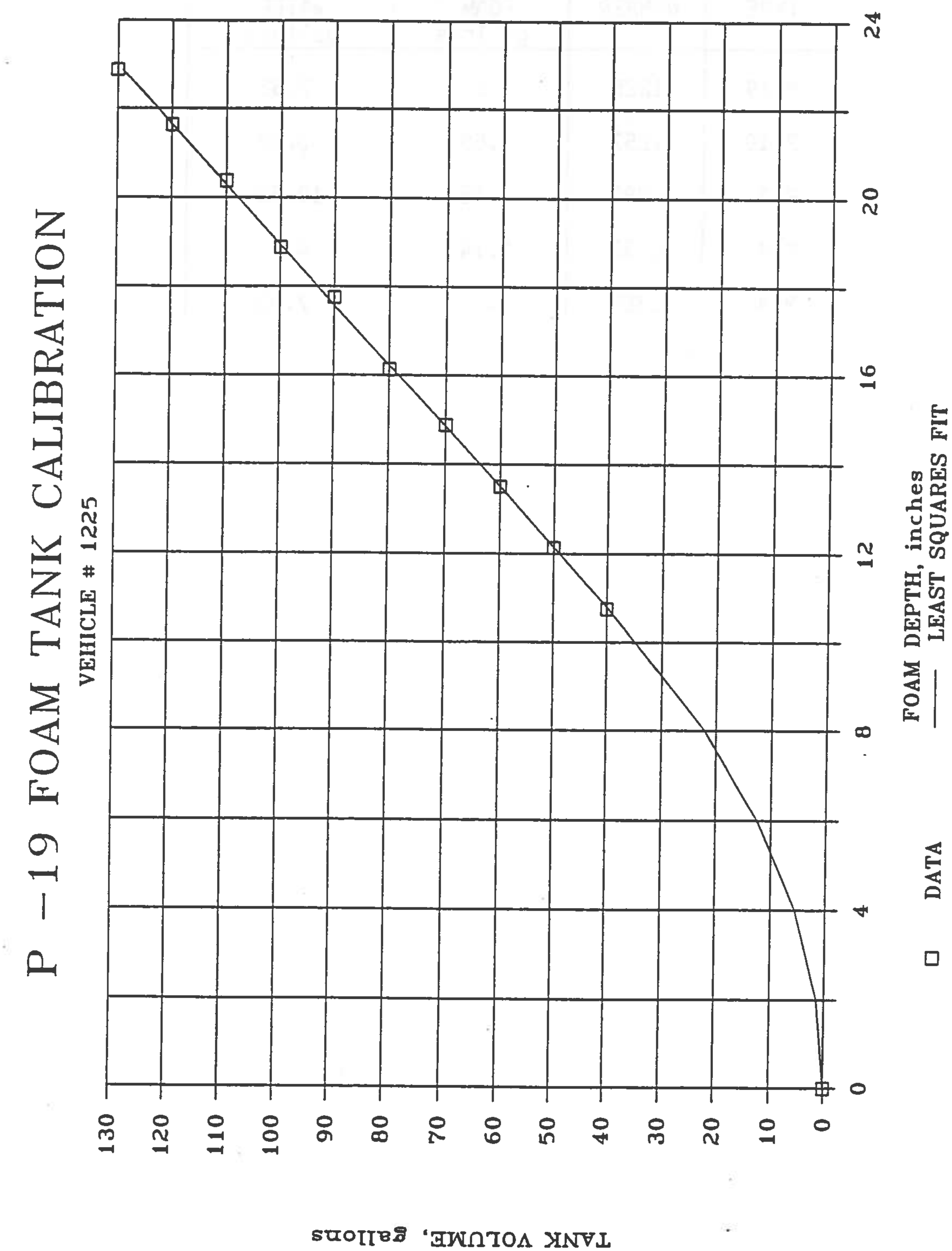

Figure A-3. P-19 Foam Tank Calibration

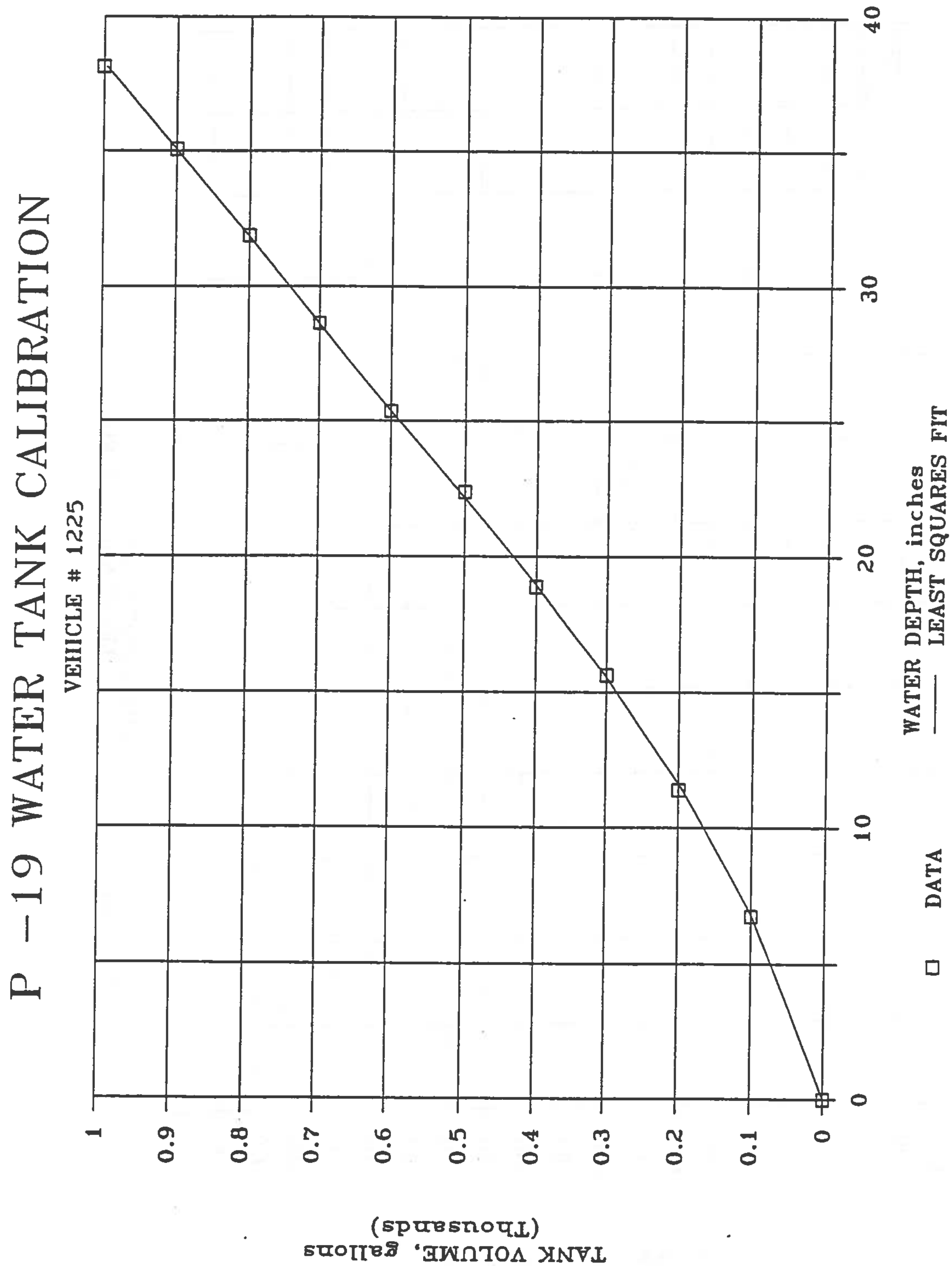

Figure A-4. P-19 Water Tank Calibration

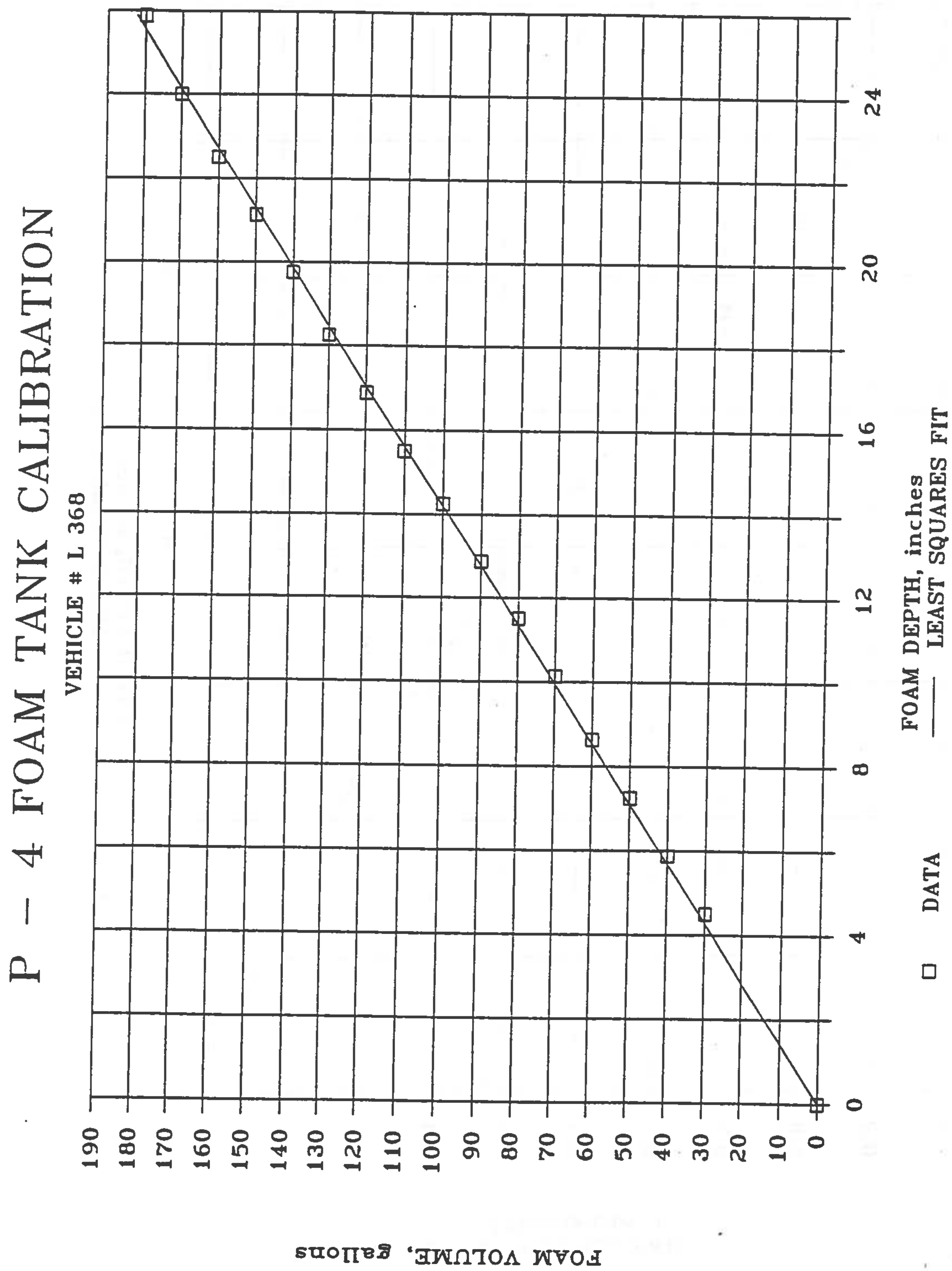

Figure A-5. P-4 Foam Tank Calibration

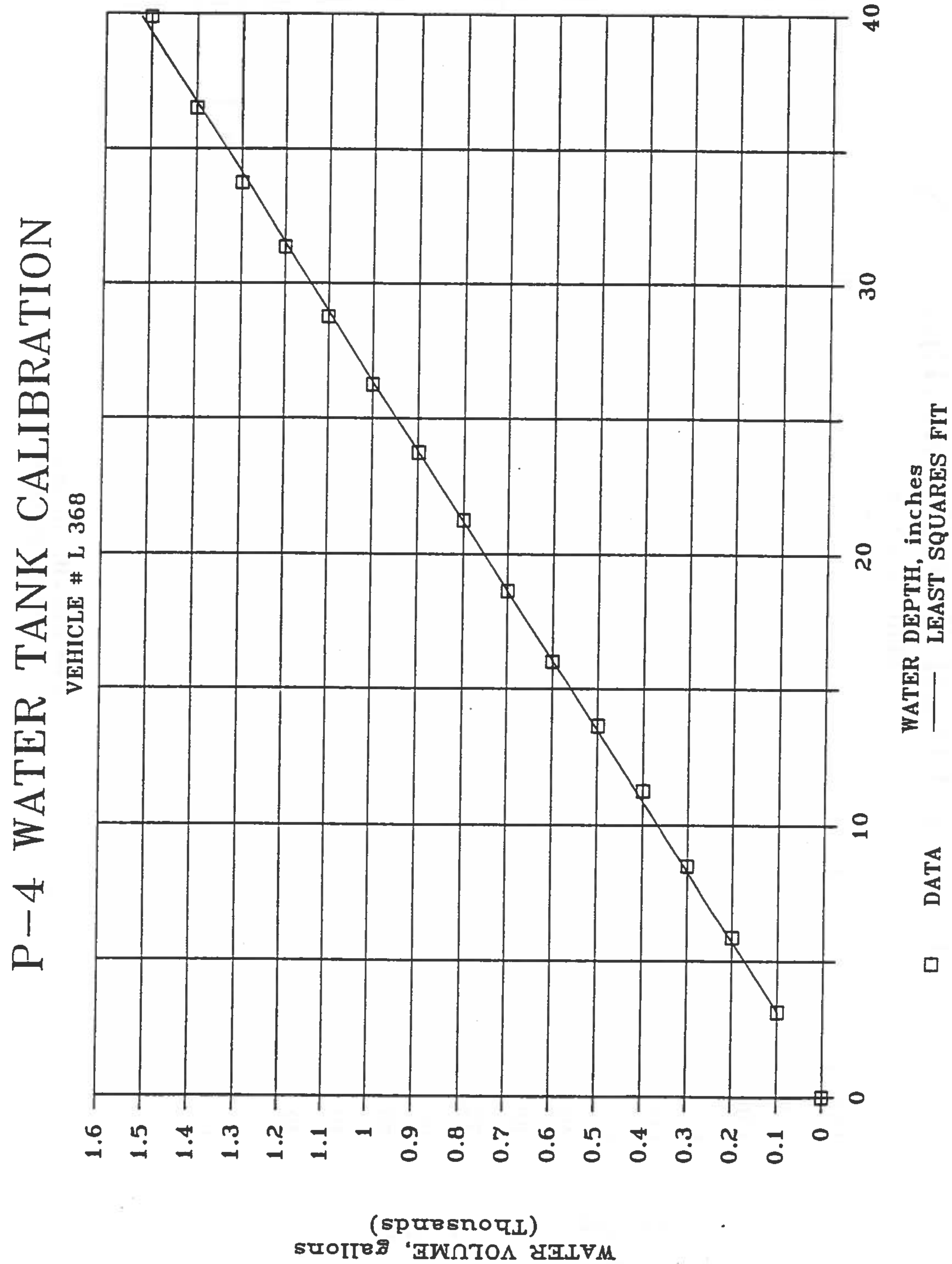

Figure A-6. P-4 Water Tank Calibration

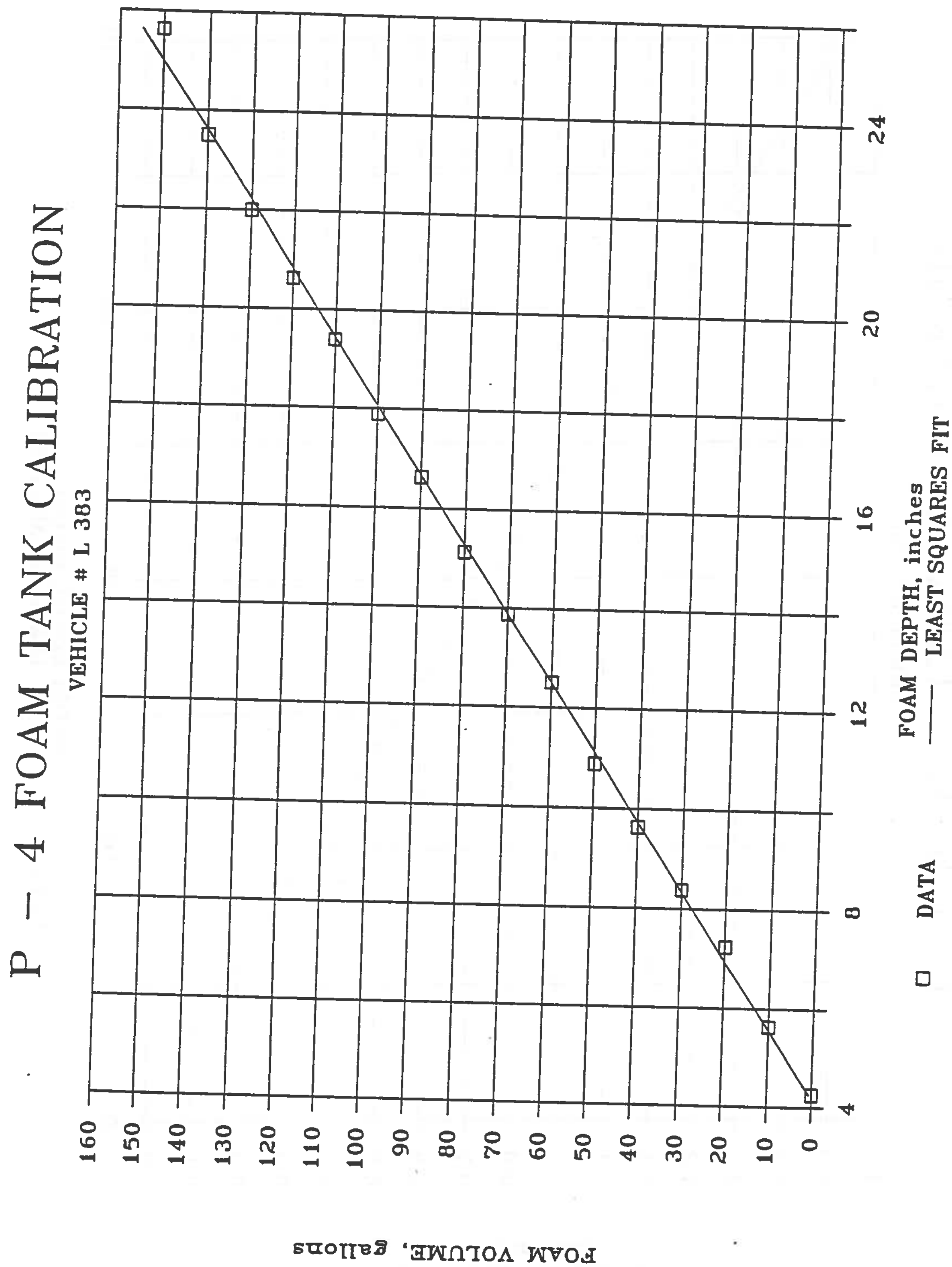

Figure A-7. P-4 Foam Tank Calibration

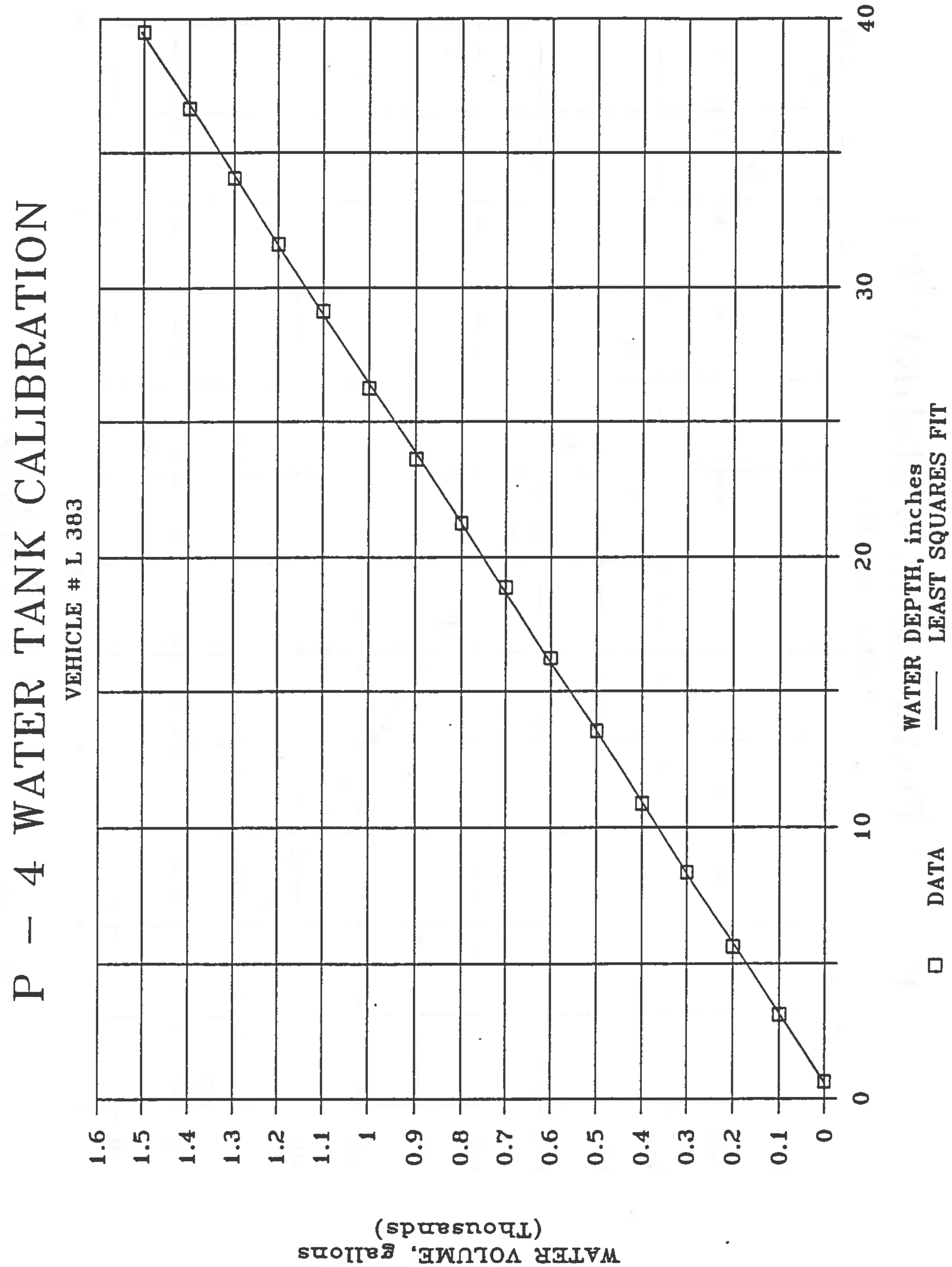

Figure A-8. P-4 Water Tank Calibration

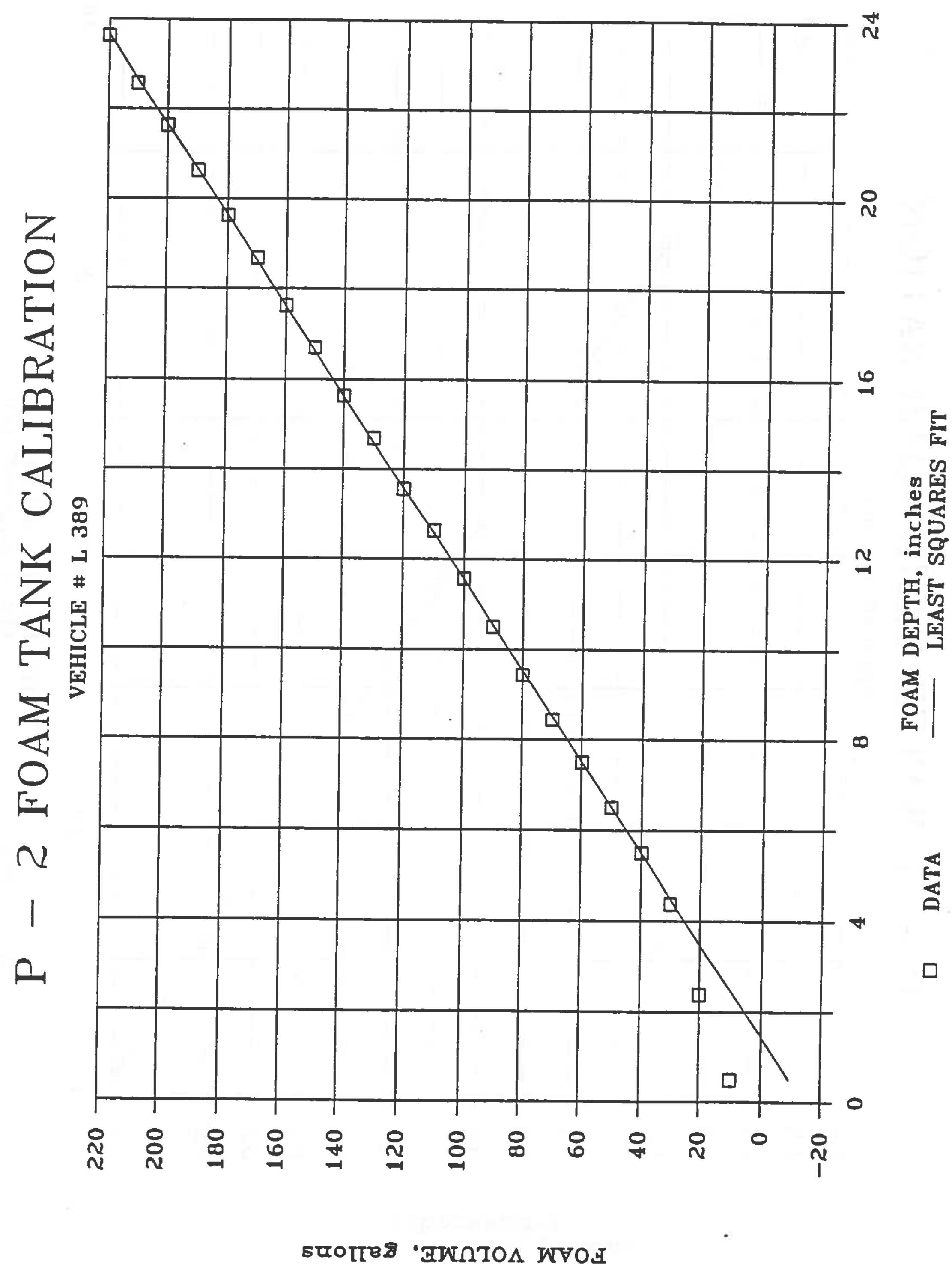

Figure A-9. P-2 Foam Tank Calibration

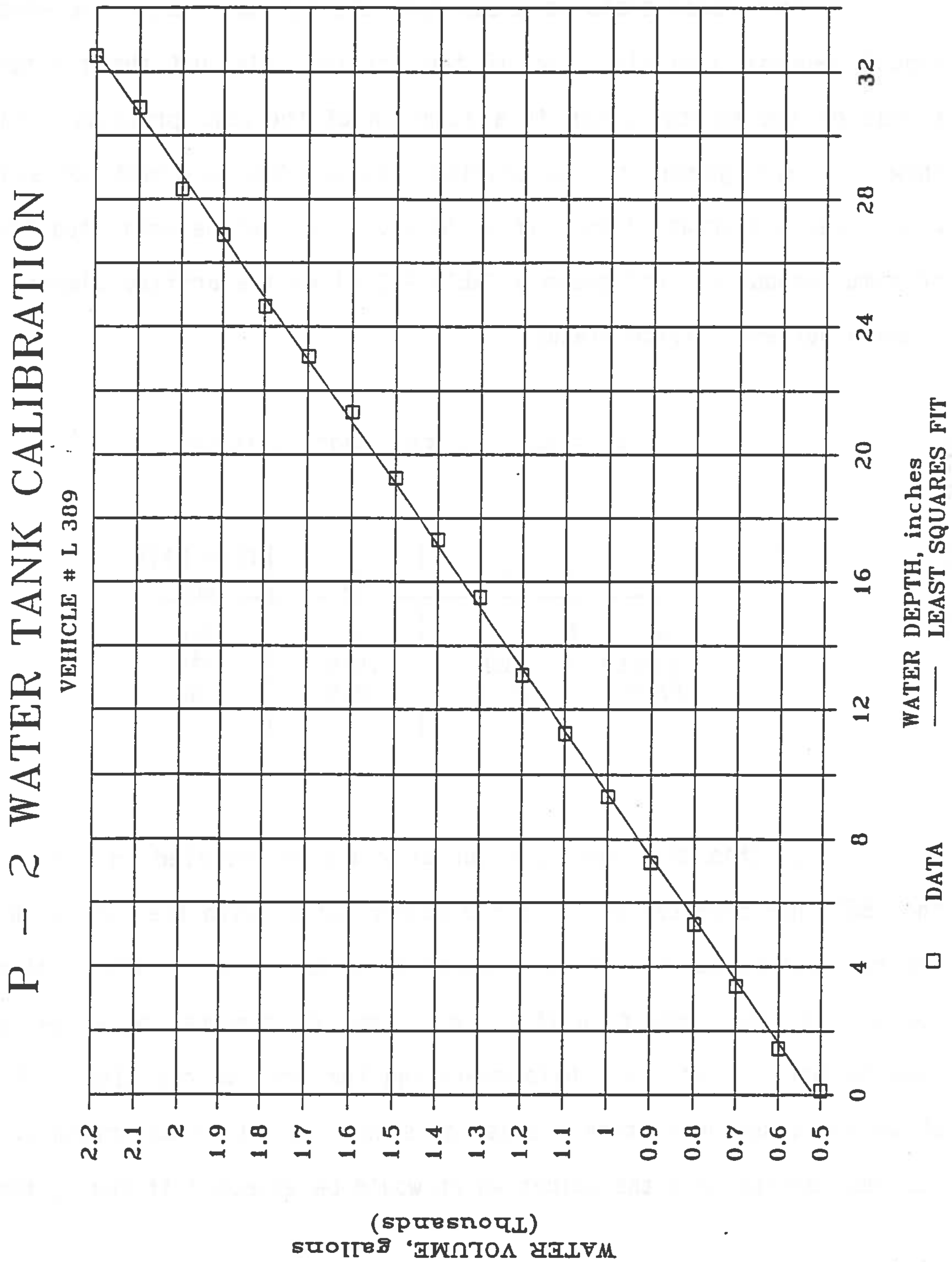

Figure A-10. P-2 Water Tank Calibration

and a nozzle discharge loop. The amount of agent discharged from the turret depends only upon the pump pressure at the regulator. Likewise, the amount of fluid circulating in the foam loop depends primarily on the pump pressure.

Foam concentrate is drawn into the system through the eductor. The amount depends upon the size of the orifice hole and the pressure in the throat of the eductor which is a function of the pump pressure. Figure A-12 shows the arrangement of the orifice system. The manifold contains a plate with three different sized orifice holes. Each can be activated individually or simultaneously. For example Table A-3 gives the orifice diameters for the 3 and 6 percent orifice plates.

TABLE A-3. ORIFICE SIZES - INCHES

	3%	6%	FLOW RATE gpm
Roof	.531	.812	500
Bumper	.358	.575	250
Hand	.171	.219	60

In this case the roof turret would be operated in conjunction with the .531 inch diameter orifice; the bumper turret with the .358 inch, etc. If the roof and bumper turret were operated together, both orifice holes would be opened. A wide range of mixture ratios may be produced by actuating various combinations of orifices while operating the roof turret alone. Figure A-13 shows the expected mixture ratios for such a series of experiments. The bars labeled "design" are the values which would be expected if the system metered

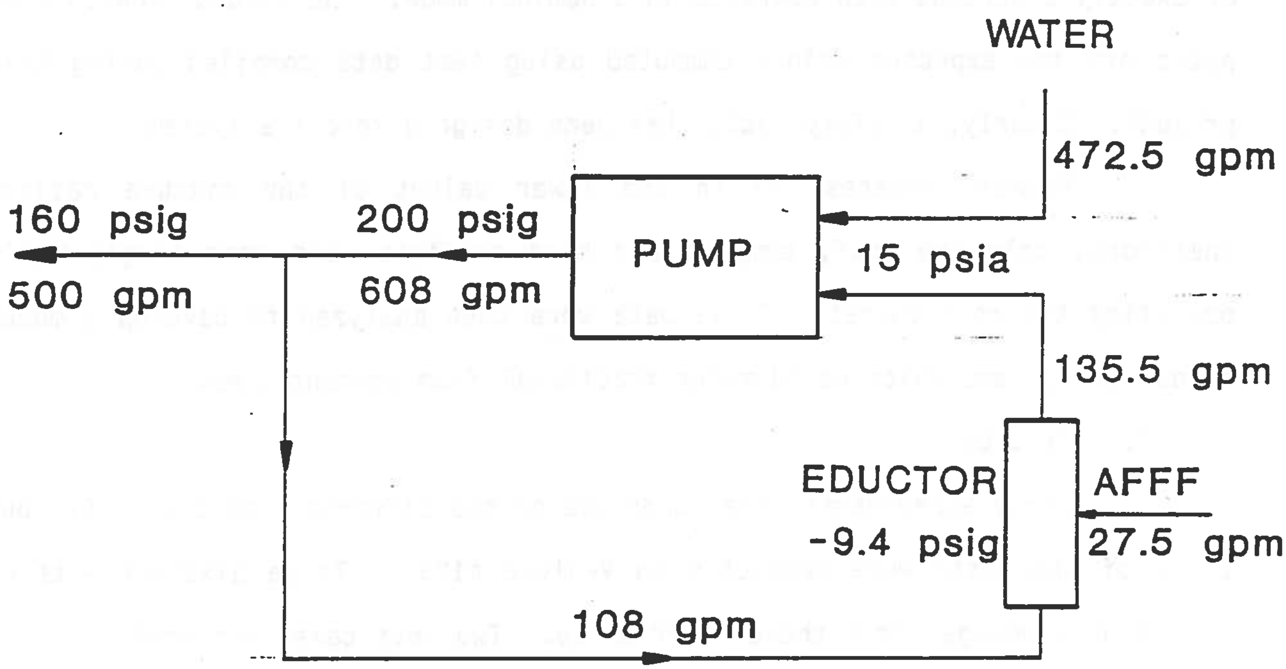

Figure A-11. P-19 Metering System

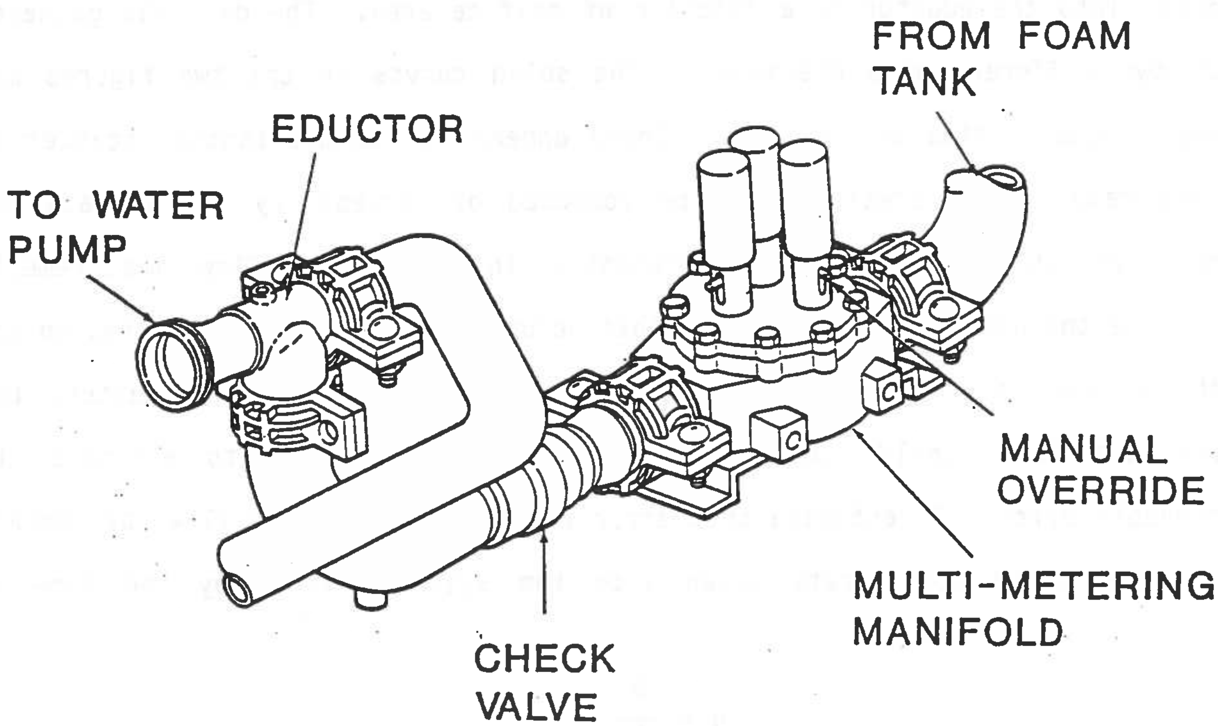

Figure A-12. Foam Proportioning System

at exactly 3 percent when operated in a nominal mode. The values labeled computed are the expected values computed using test data compiled during this project. Clearly, a safety factor has been designed into the system.

Primary interest is in the lower values of the mixture ratios; therefore, only the roof, bumper, and hand orifices were used singly while operating the roof turret. These data were then analyzed to develop a model to design systems which could meter fractional foam concentrates.

2. Test Data

Fifty experiments were conducted on two different vehicles. All but three of the tests were conducted on Vehicle #1257. Three distinct sets of usable data emerged from these experiments. Two sets came from Vehicle #1257 with the pump pressure valve set at 200 and then 220 psig. The third set came from Vehicle #1225.

Figures A-14 and A-15 show the amount of foam concentrate being drawn into the eductor as a function of orifice area. The data was gathered at two different pump pressures. The solid curves in the two figures are least squares fits to the data. There appears to be substantial scatter in this data. This scatter could be composed of variability in the data and round off while making the measurements. In every case flow measurements include the non-steady flow period that occurs when the valve is turned on and the system is coming up to speed. This will contribute to scatter, but reflects "real world" conditions. An attempt was made to estimate the roundoff error. To estimate this error recall that the foam flow rate equals the amount of concentrate drawn into the system divided by the time or

$$q = \frac{Q}{t}$$

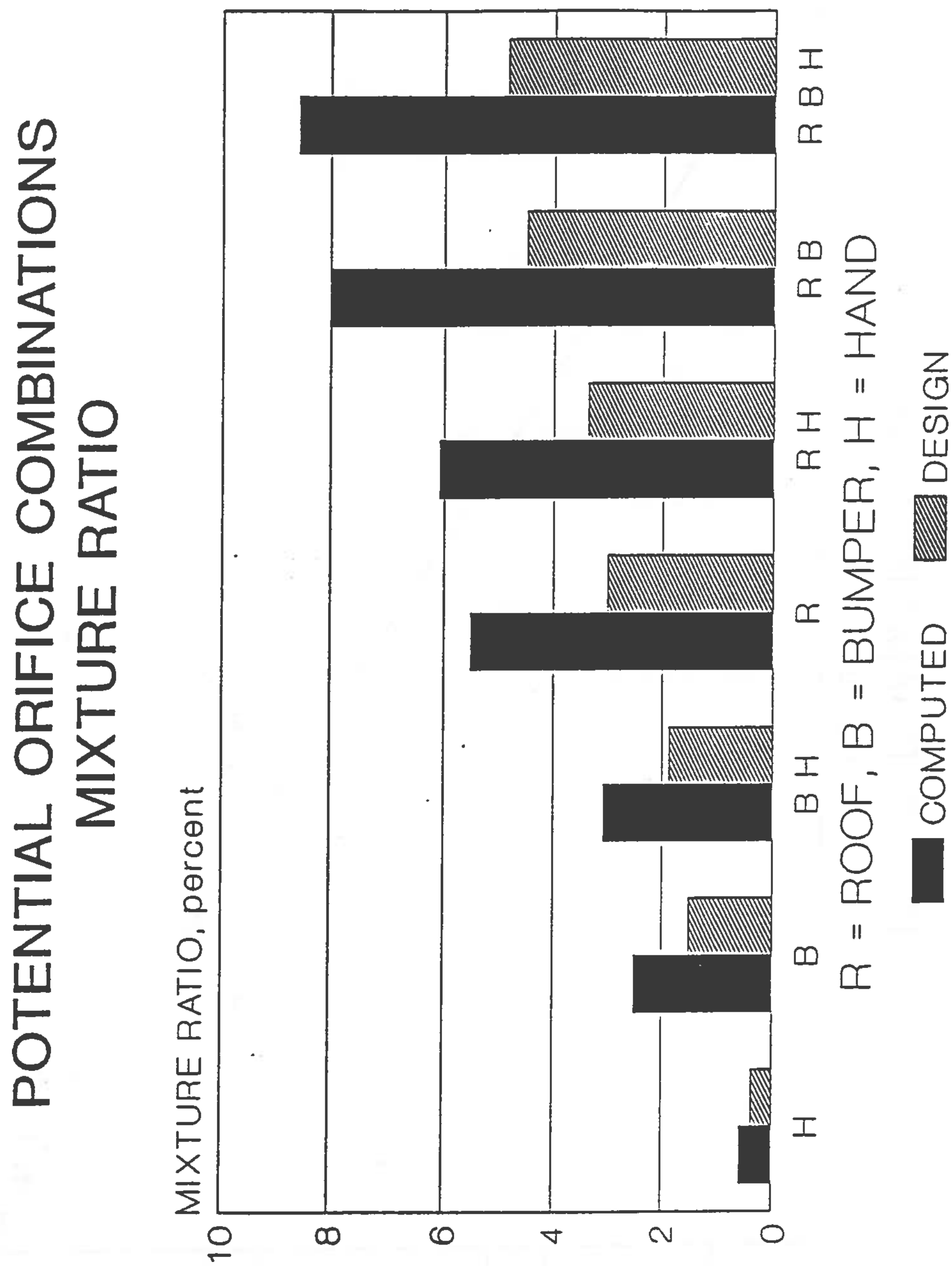

Figure A-13. Potential Orifice Combinations Mixture Ratio

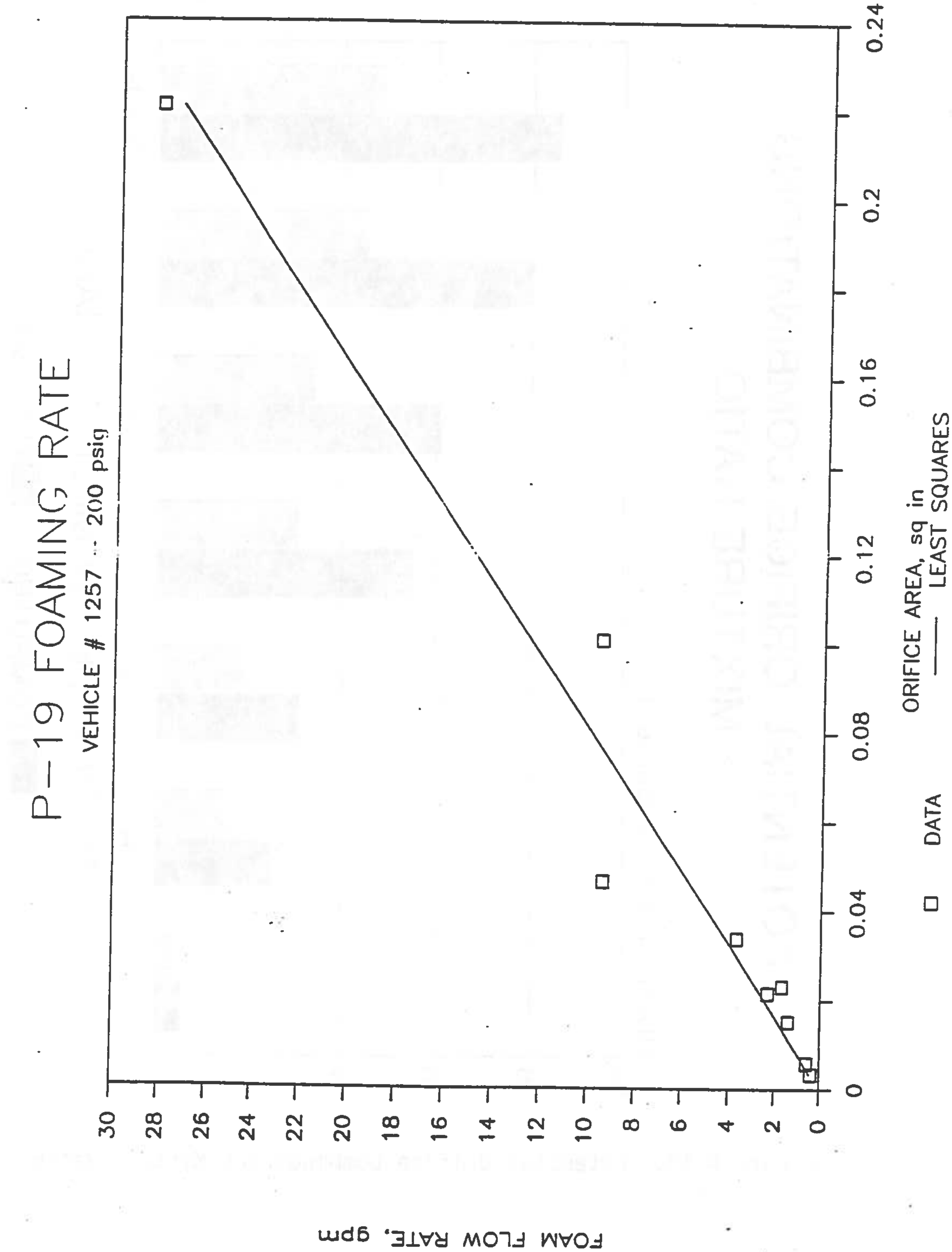

Figure A-14. P-19 Foaming Rate

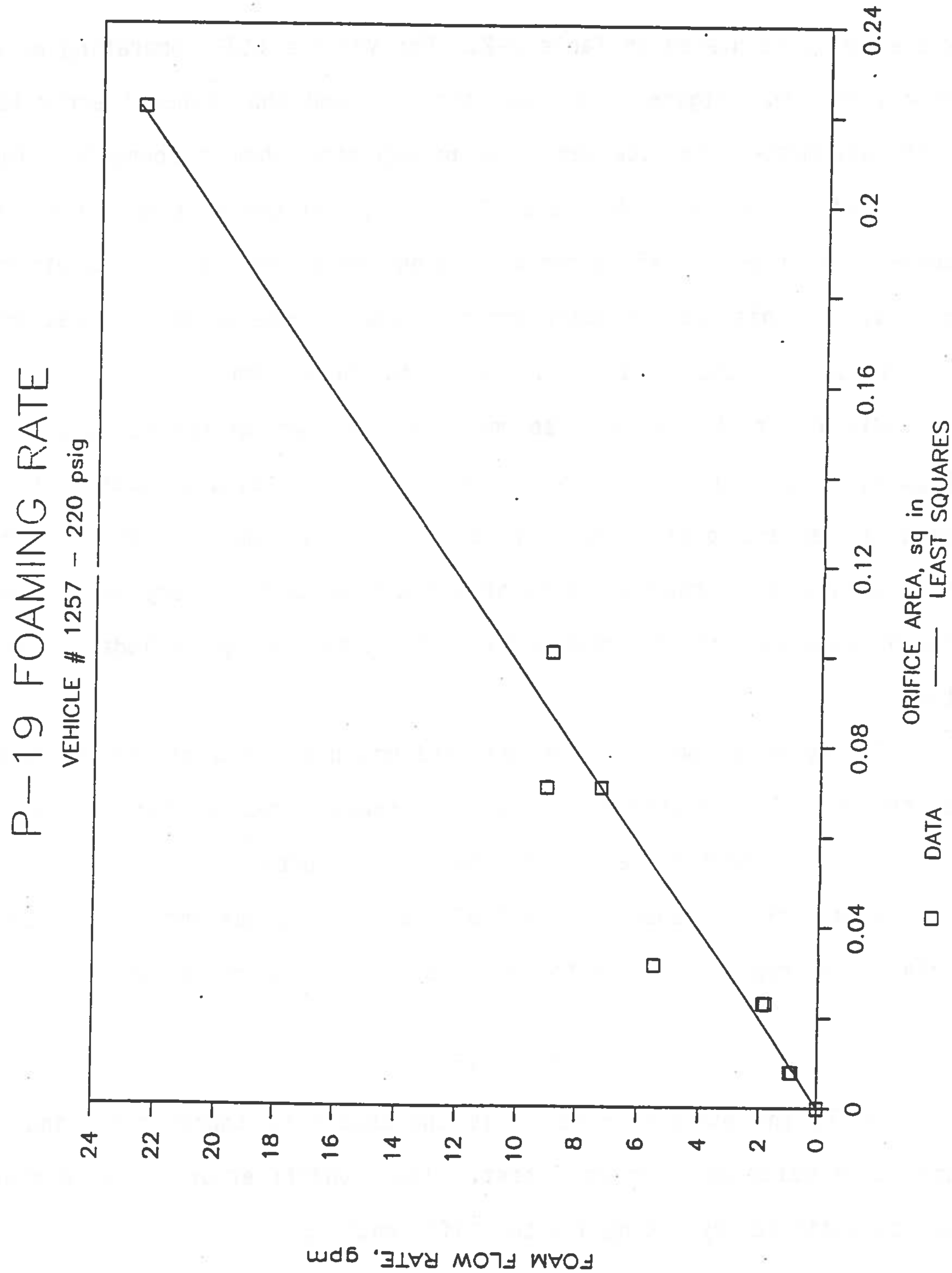

Figure A-15. P-19 Foaming Rate

Therefore, the error in the flow rate is

$$\Delta q = \frac{\Delta Q}{t}$$

where ΔQ is tabulated in Table A-2. For Vehicle #1257 operating at 220 psig $\Delta q \approx 1.36$ gpm. Figure A-16 shows the data and the roundoff error band. In this case most of the scatter could be explained due to roundoff. The second series of tests was conducted at 200 psig, and the test durations were much longer. Figure A-17 shows the data along with the maximum and minimum error bounds. In this case roundoff error is small compared to the scatter, and it must be assumed that scatter is inherit to the system.

Mixture ratios were also measured at two different pump pressures. Figures A-18 and A-19 show this data. Its interesting to note that the standard 3 percent orifice has an area of 0.22 square inches. This area corresponds to a measured ratio of about 5 percent. Every vehicle which was tested metered rich; it appears that the system design includes a safety factor.

Figure A-20 compares the measured mixture ratio at two different pump pressures. As expected higher pump pressures produce lower mixture ratios. This is due to higher pressure in the eductor throat.

This data also shows substantial scatter. As was done with the foam flow data an attempt was made to estimate the roundoff error. In this case

$$n = \frac{c}{c+w}$$

where n is the mixture ratio, c is the amount of concentrate, and w is the amount of water used during a test. The roundoff error in the mixture ratio may be estimated by taking a total differential:

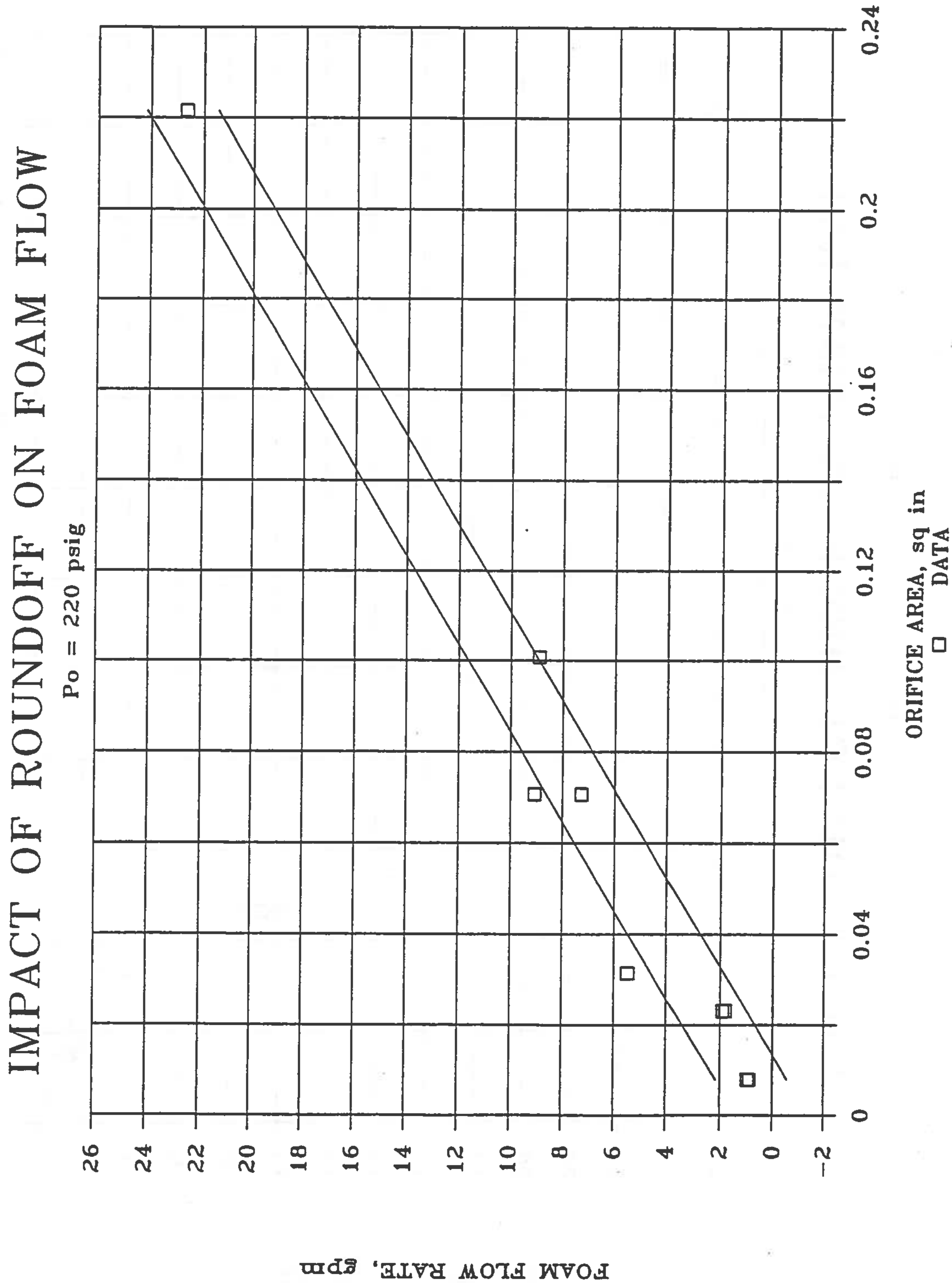

Figure A-16. Impact of Roundoff on Foam Flow

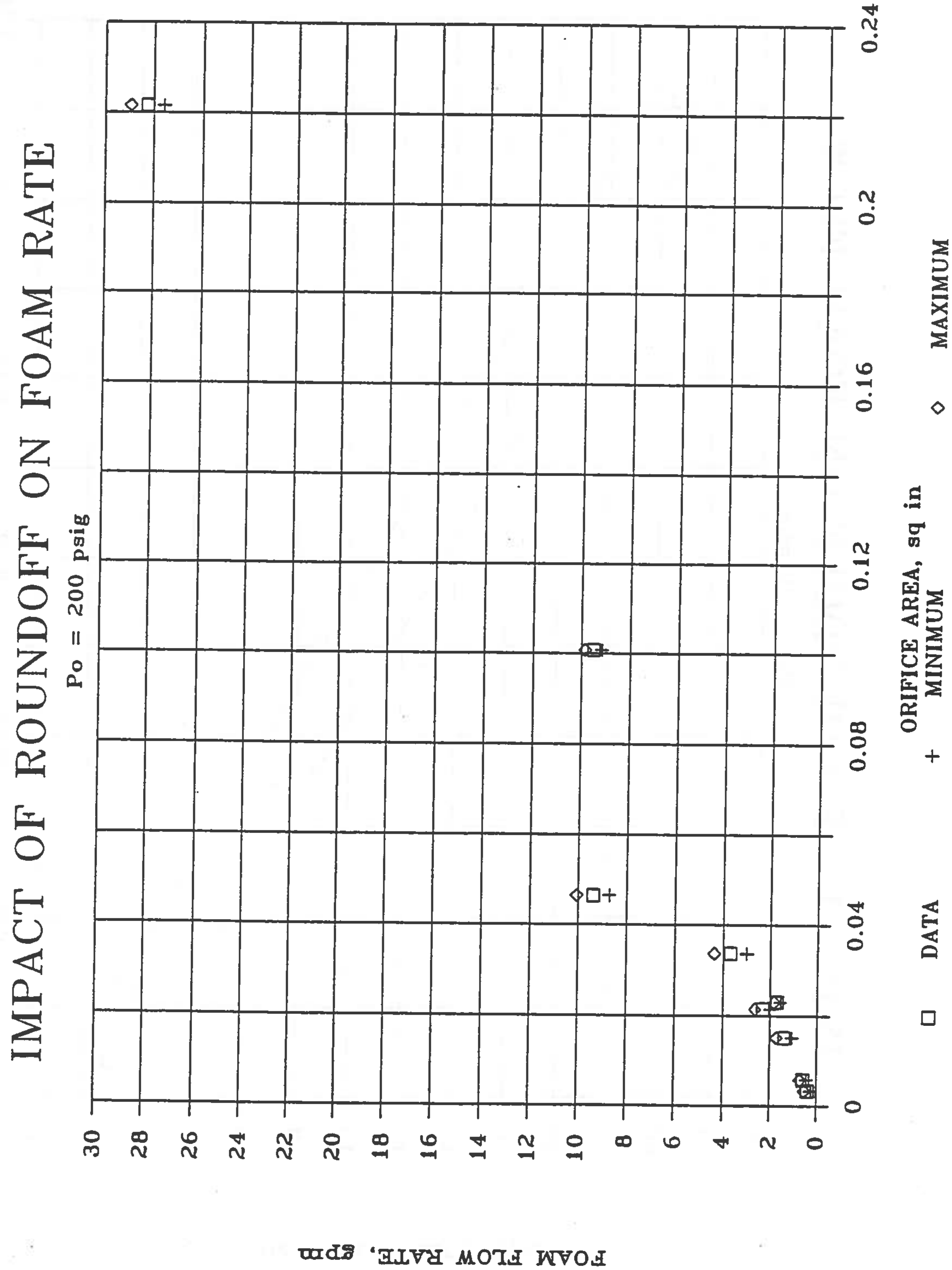

Figure A-17. Impact of Roundoff on Foam Rate

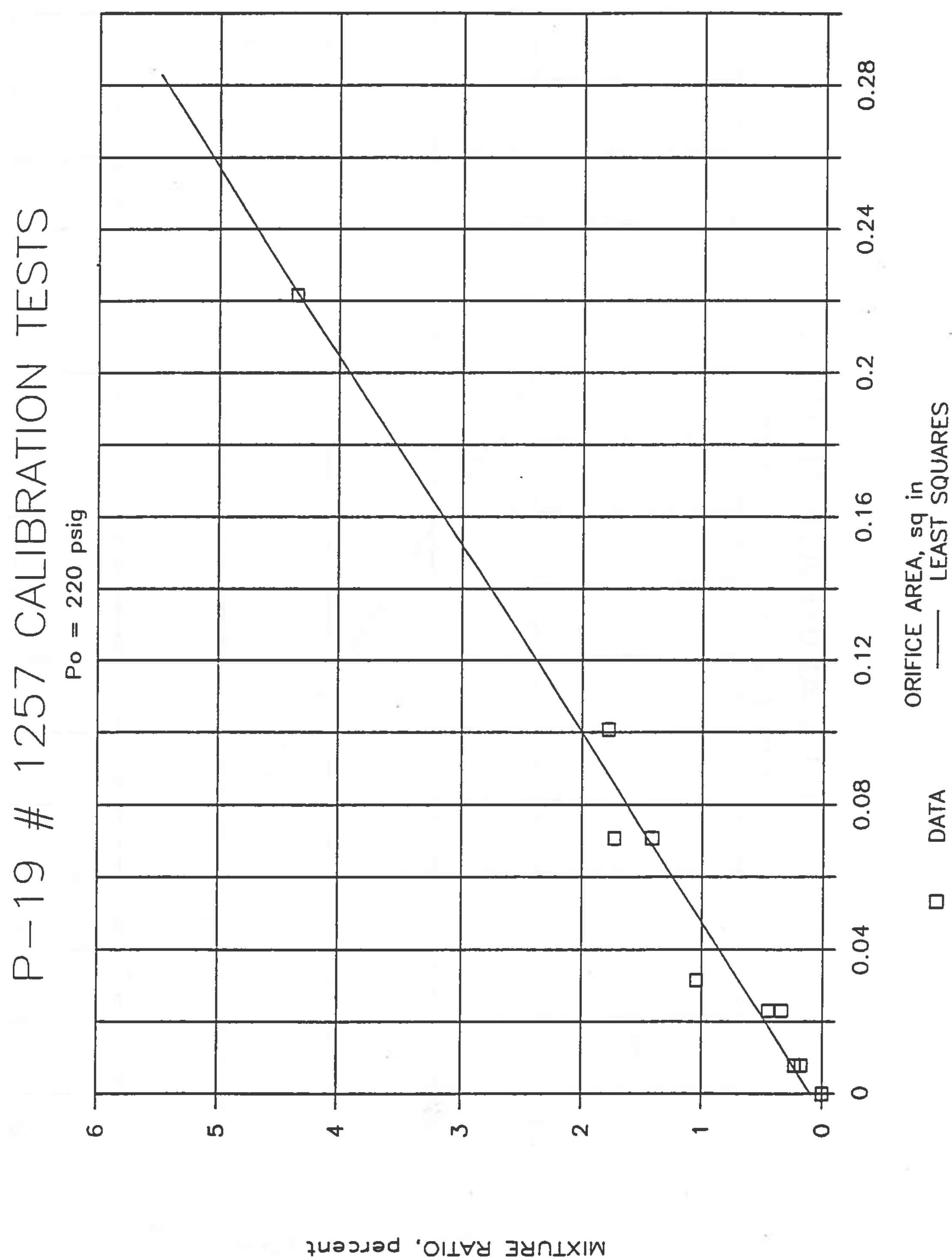

Figure A-18. P-19 #1257 Calibration Tests

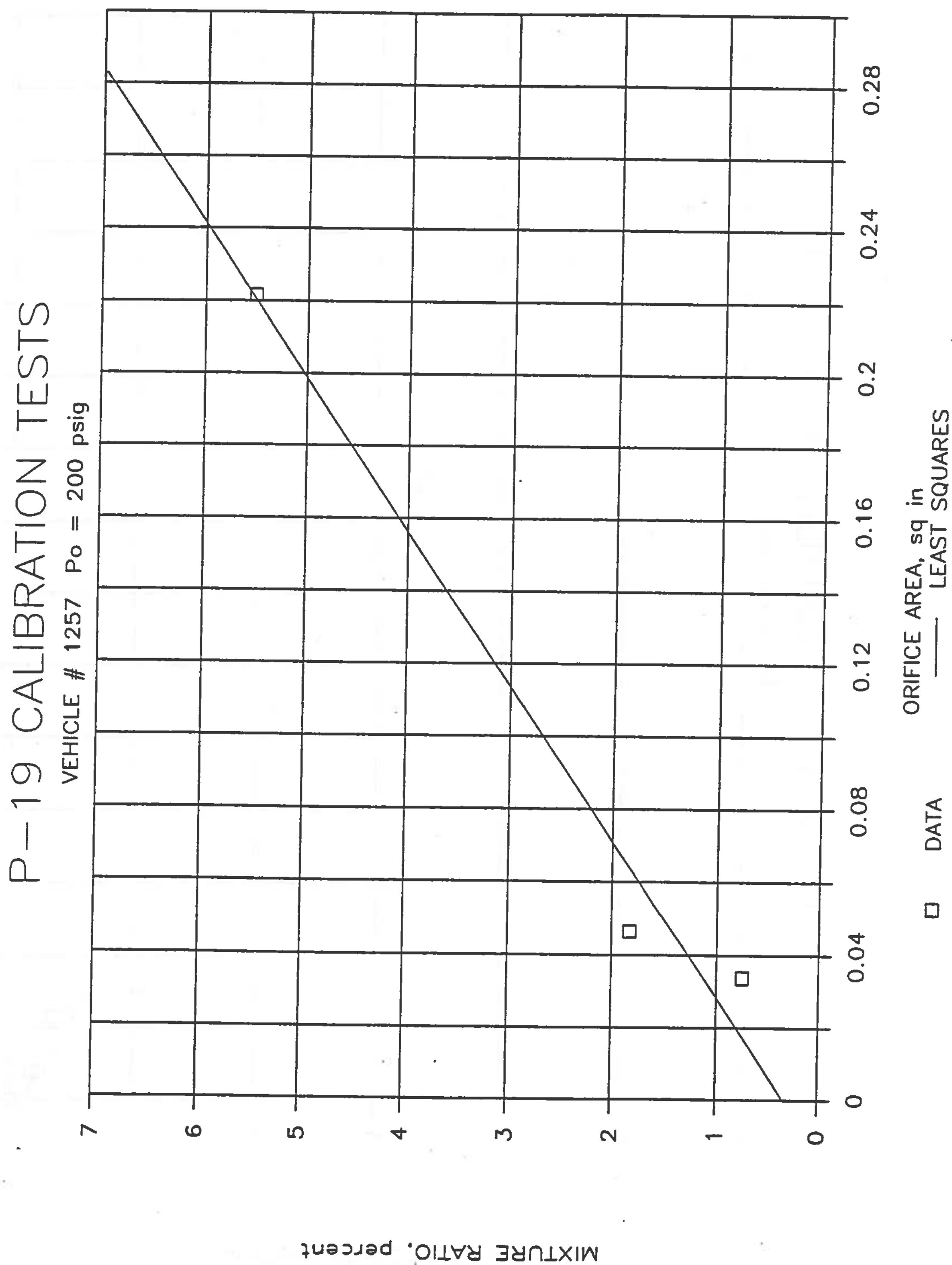

Figure A-19. P-19 Calibration Tests

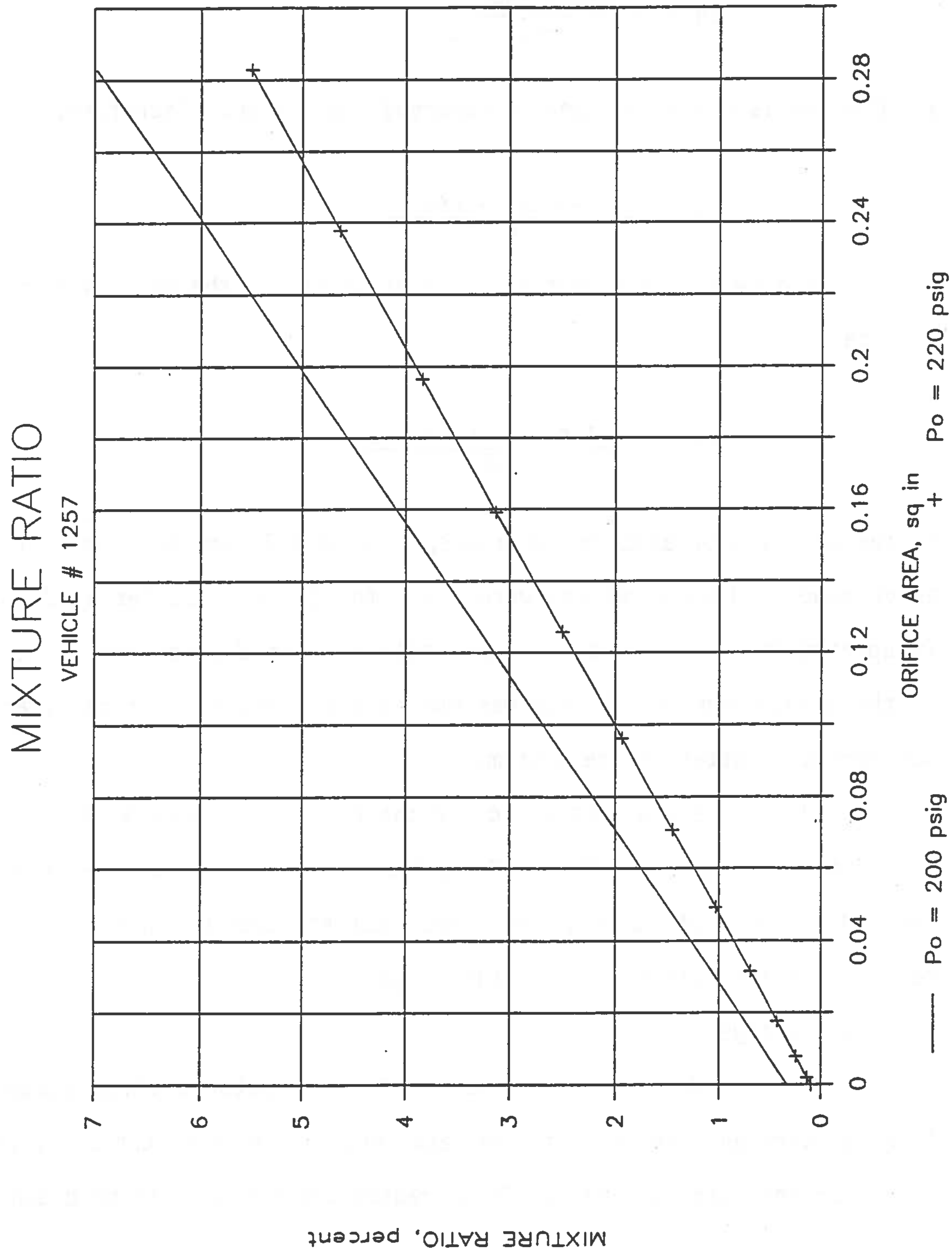

Figure A-20. Mixture Ratio

$$\Delta n = \left[\frac{\partial n}{\partial c} \right]_w \Delta c + \left[\frac{\partial n}{\partial w} \right]_c \Delta w$$

or

$$\Delta n = \frac{w\Delta c - c\Delta w}{(c+w)^2}$$

but $Q = c+w$ is the total agent discharged and $c = nQ$. Therefore,

$$\Delta n = \frac{(1-n)\ \Delta c - n\Delta w}{Q}$$

Since Δc and Δw can be either positive or negative, the maximum roundoff error will be

$$\Delta n = \frac{(1-n)\ |\Delta c| + n\ |\Delta w|}{Q}$$

Δw and Δc are tabulated in Table A-2, Figures A-21 and A-22 show the roundoff error bands. Test durations were short for the test series at 220 psig, and it appears that the roundoff error could explain the scatter. The durations of the series run at 200 psig was much longer, and it is clear that there is substantial scatter in the system.

The discharge characteristics of the three nozzles were observed for pump pressures ranging from 200 to 300 psig. Figure A-23 compares the discharge rates for the roof turret, the bumper turret, and the hardline. Discharge rates are nearly constant over this range.

3. Analysis

Figure A-24 is a schematic of the eductor-orifice system. Agent flowing through the eductor is accelerated in the throat (A_1) with a corresponding pressure drop. This causes concentrate to be drawn into the

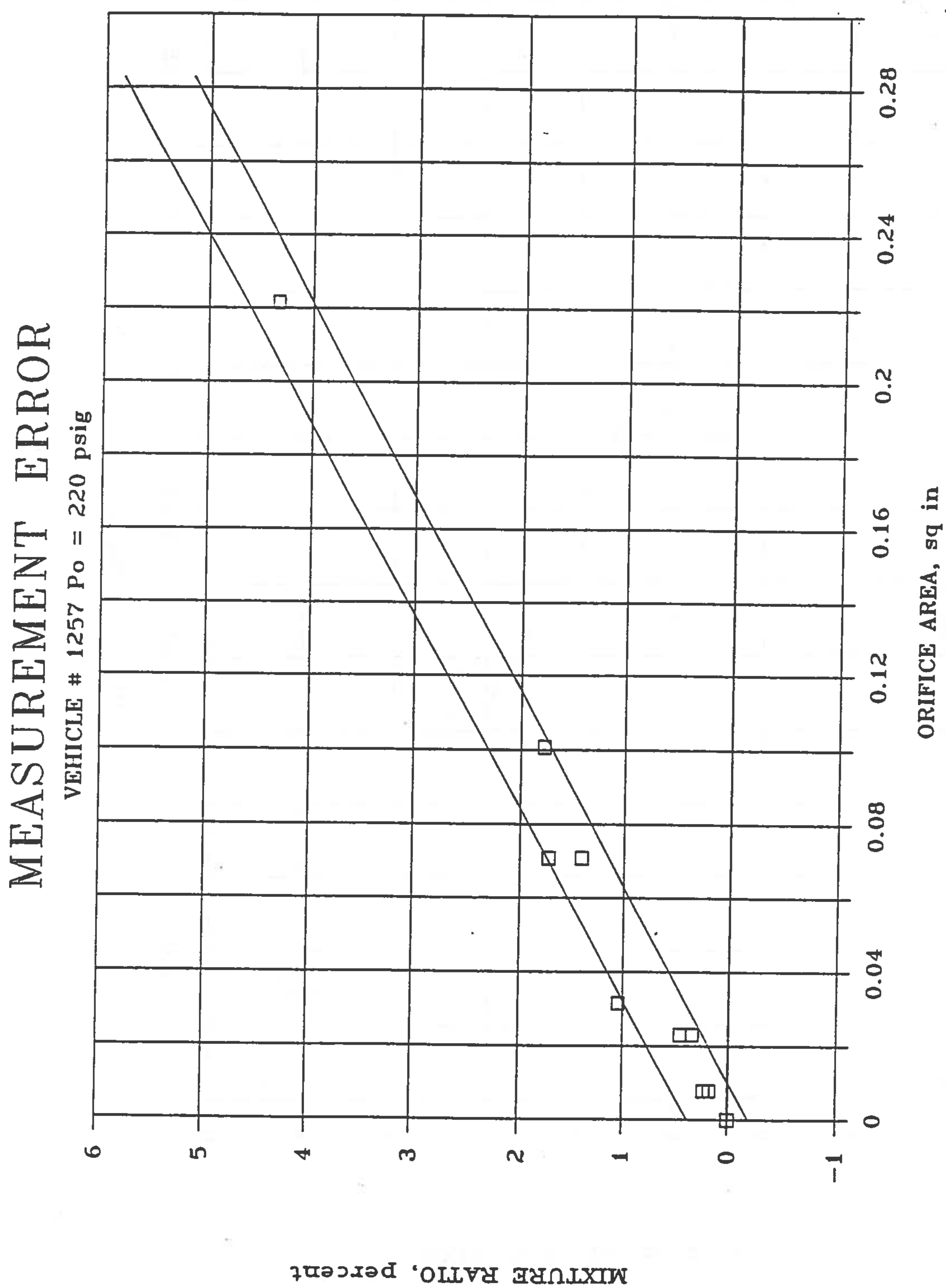

Figure A-21. Measurement Error

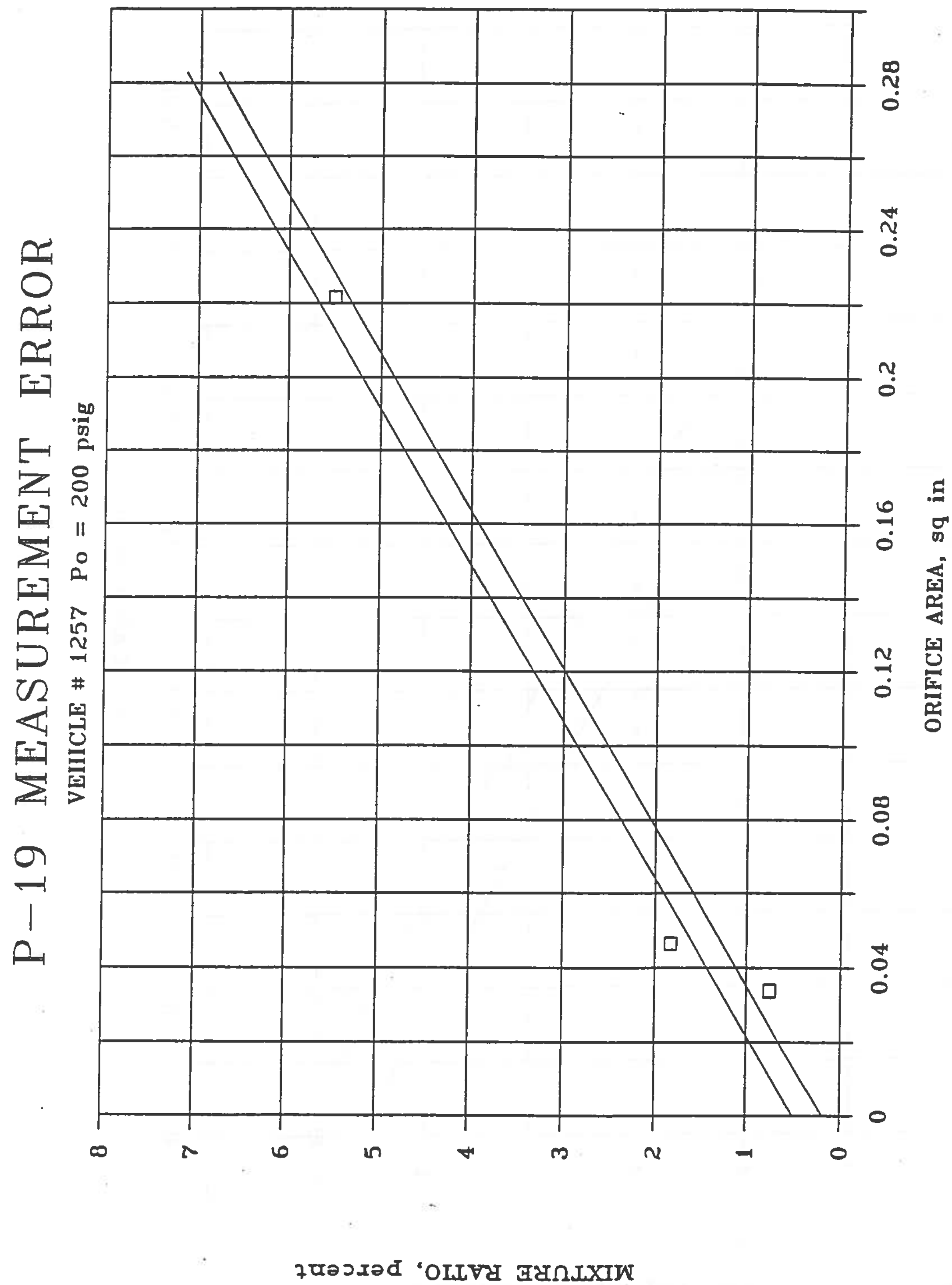

Figure A-22. P-19 Measurement Error

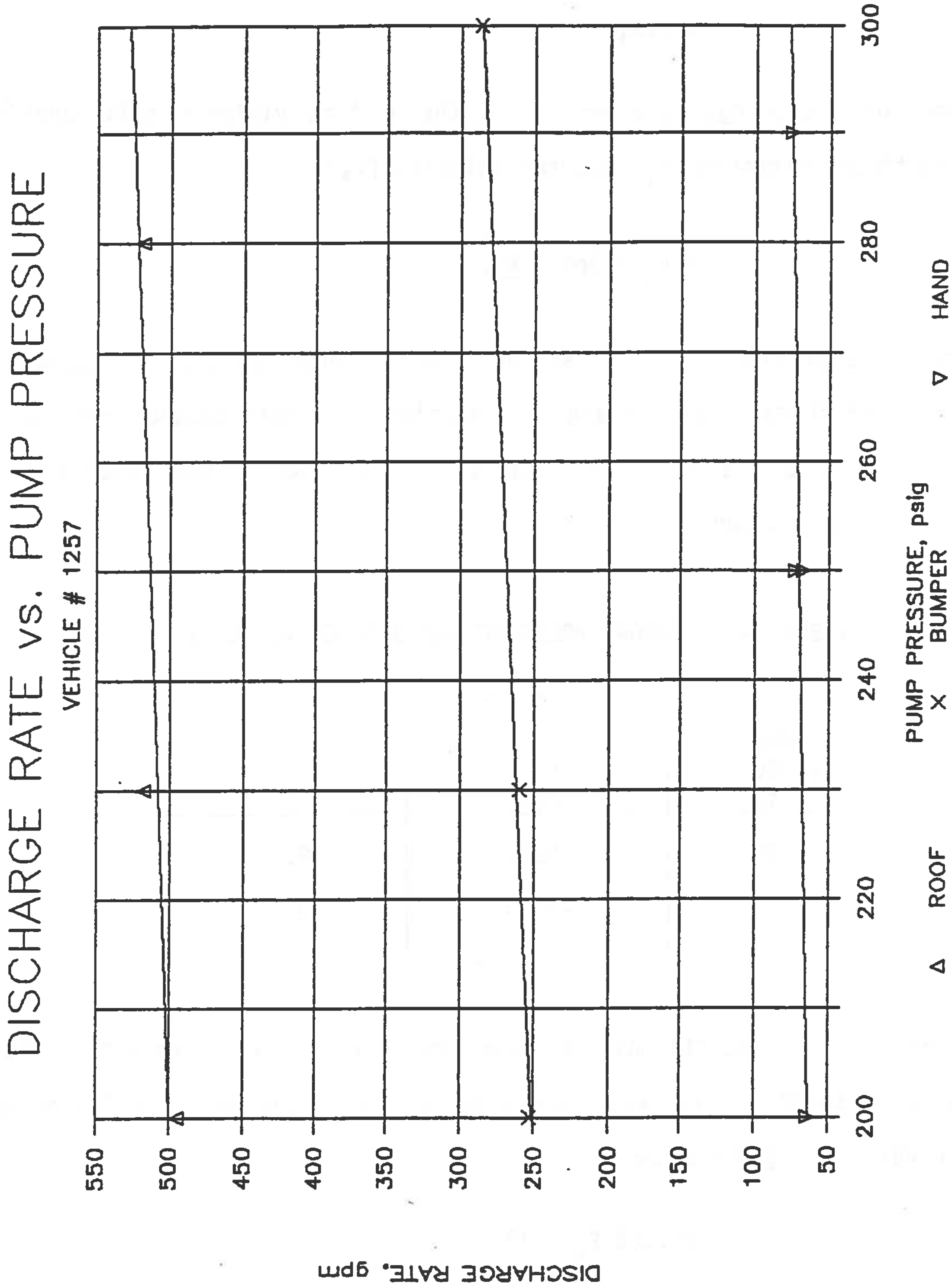

Figure A-23. Discharge Rate vs. Pump Pressure system. The foam flow rate is know from the experiments. Given this foam rate we can compute the velocity through the orifice (V_3).

$$Q_3 = V_3 A_3$$

Applications of the energy equation across the orifice yields a relationship between the throat pressure (P_T) and the velocity (V_3):

$$P_T = P_a + 3\rho G - \frac{PV_3^2}{2}$$

P_a is atmosphere pressure, and the second term accounts for a 3 foot head on the orifice. If these equations are solved using the least squares representations of the data presented in Figures A-14 and A-15, one obtains the following values of P_T and V_3.

TABLE A-3. THROAT PRESSURE AND ORIFICE VELOCITY

PUMP PRESSURE psig	P_T psig	V_3 fps
200	-9.40	39.9
220	-6.04	33.0

Throat pressure is proportional to pump pressure (with a correction for velocity), and assuming this relationship to be linear one gets the following expression while using the data:

$$P_T \approx .168\ P_o - 43$$

Since the throat pressure and orifice velocity are known as a function of pump pressure, its a simple matter to compute the foam flow rate as well as all the other parameters. Application of the energy equation across the eductor yields an expression for the throat velocity:

$$V_1 = \sqrt{\frac{2\,(P_0 - P_T)}{\rho}}$$

and

$$Q_1 = A_1 V_1$$

The exit velocity (V_2) may be computed using the continuity equation:

$$V_2 = \frac{A_1 V_1 + A_3 V_3}{A_2}$$

The energy into the system is known

$$E_1 = Q_1 \frac{P_0}{\rho}$$

$$E_3 = q_3 \left[\frac{P_T}{\rho} + \frac{V_3^2}{2} \right]$$

Therefore,

$$E_2 = E_1 + E_3 = q_2 \left[\frac{P_2}{\rho} + \frac{V_2^2}{2} \right]$$

Simplifying

$$P_2 = \frac{\rho}{q_2} (E_1 + E_3) - \frac{\rho V_2^2}{2}$$

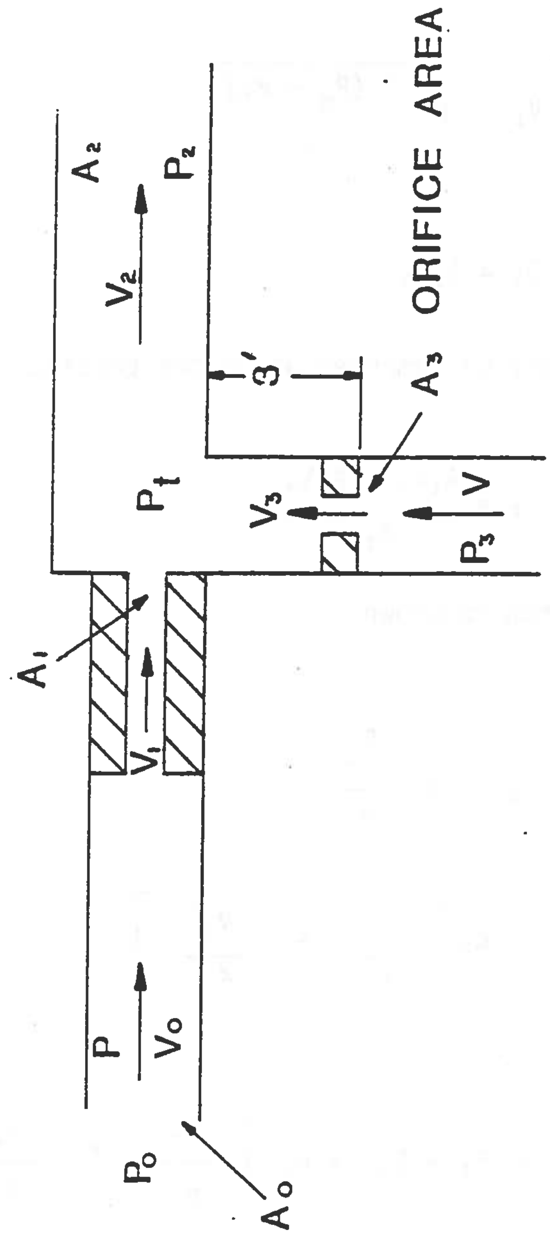

Figure A-24. P-19 Eductor

Finally, the input velocity is:

$$V_o = \frac{q_1}{A_o}$$

and

$$P = \frac{P_o}{2} - \frac{\rho V_o^2}{2}$$

is the inlet pressure to the eductor.

A small computer program was written to solve these equations and predict the characteristics of any P-19 metering system given the pump pressure and orifice diameter. Figures A-25 and A-26 compare the computed foam flow rate with the data gathered in the test program. Figures A-27 and A-28 compare mixture ratio. Figure A-29 illustrates the impact of pump pressure on mixture ratio. It can be seen that the metering system is sensitive to the setting of the pressure regulating valve.

One of the prime purposes of this analysis was to be able to design plates that would meter concentrate at 3/4 and 1 percent. Table A-4 tabulates the recommended orifice diameters needed to accomplish this task.

TABLE A-4. ORIFICE SIZES FOR METERING 3/4 AND 1 PERCENT CONCENTRATES

NOZZLE	ORIFICE DIAMETER	
	3/4%	1%
Roof	.196	.227
Bumper	.139	.160
Hand	.068	.079

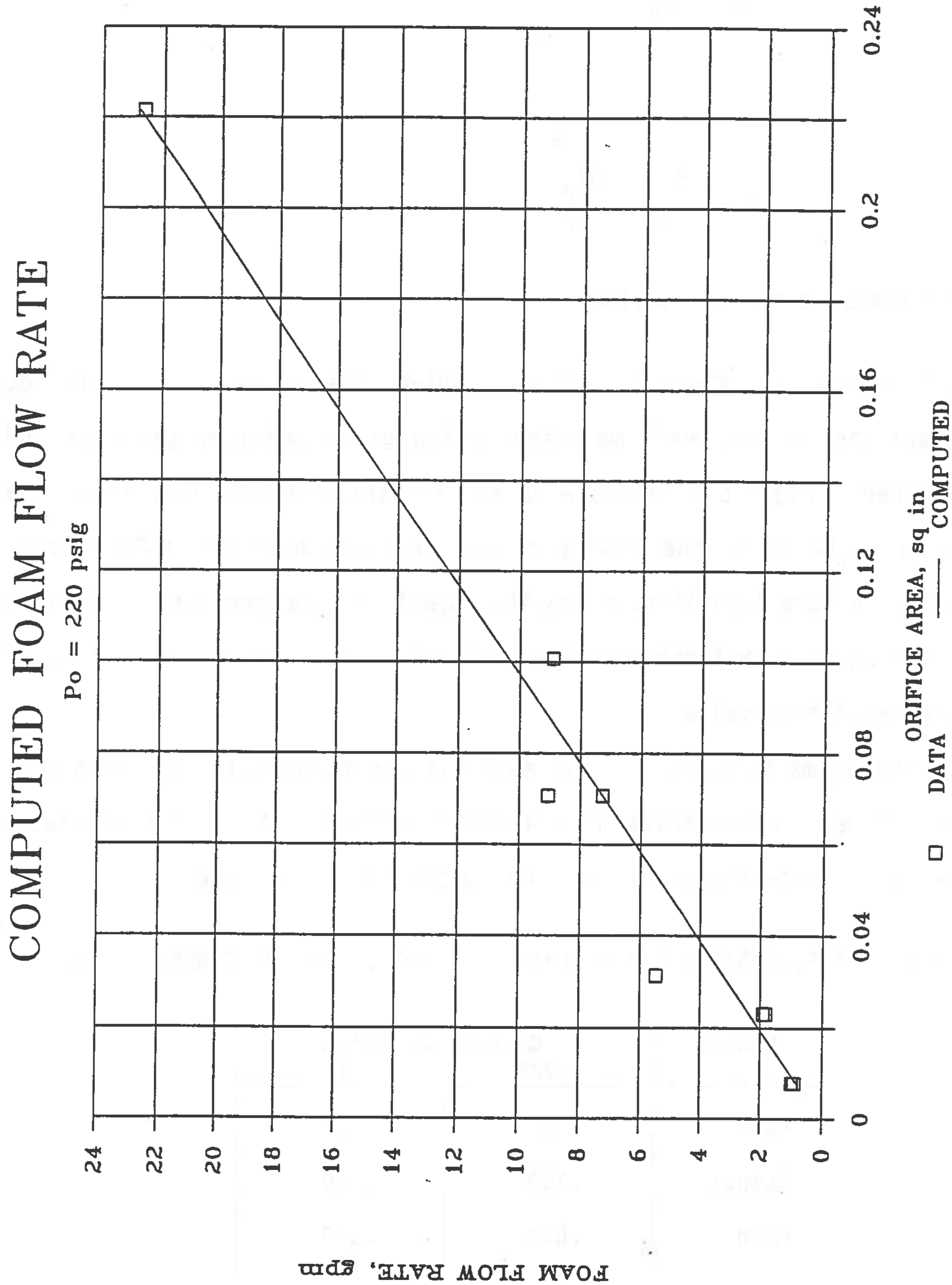

Figure A-25. Computed Foam Flow Rate

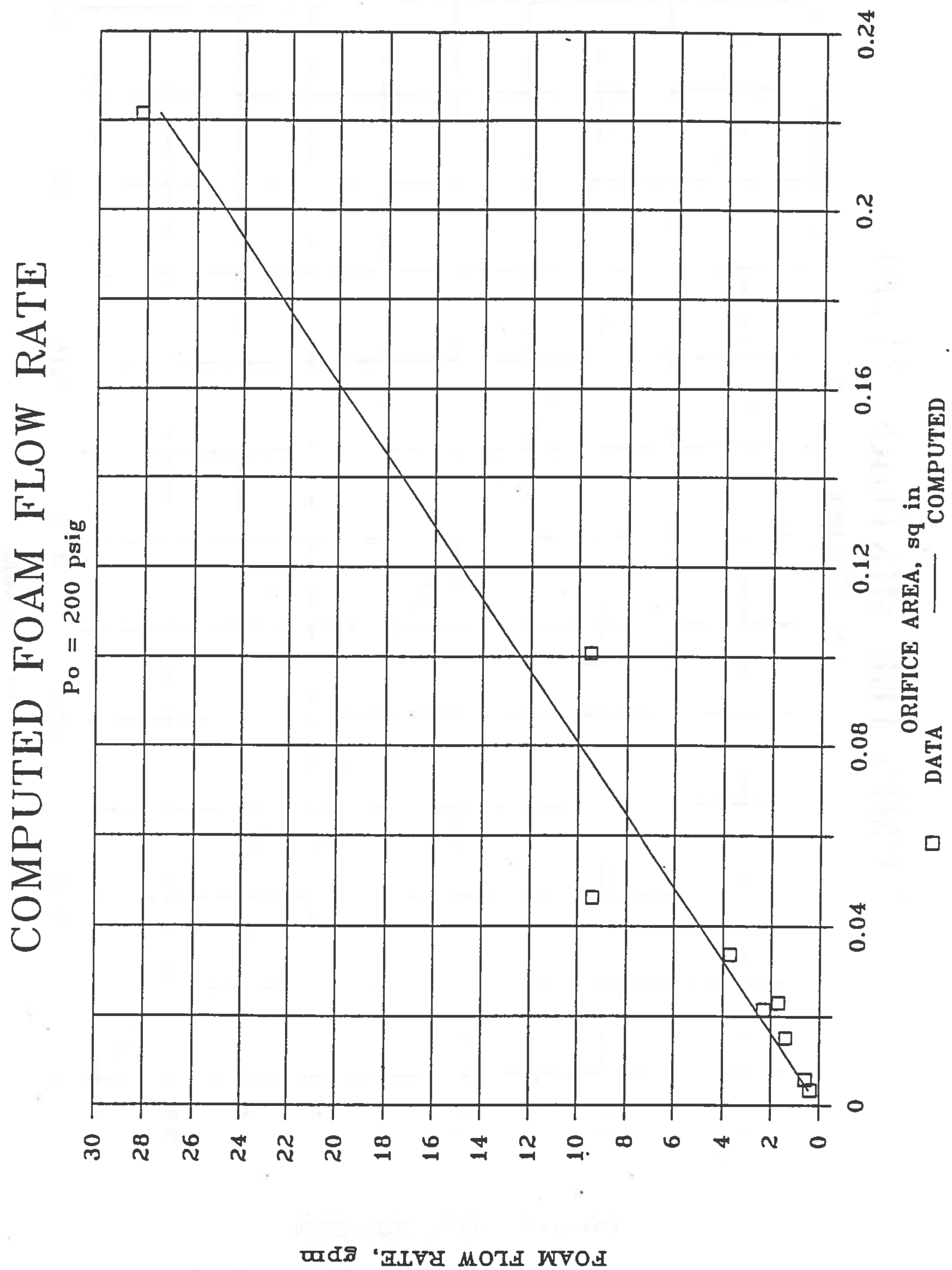

Figure A-26. Computed Foam Flow Rate

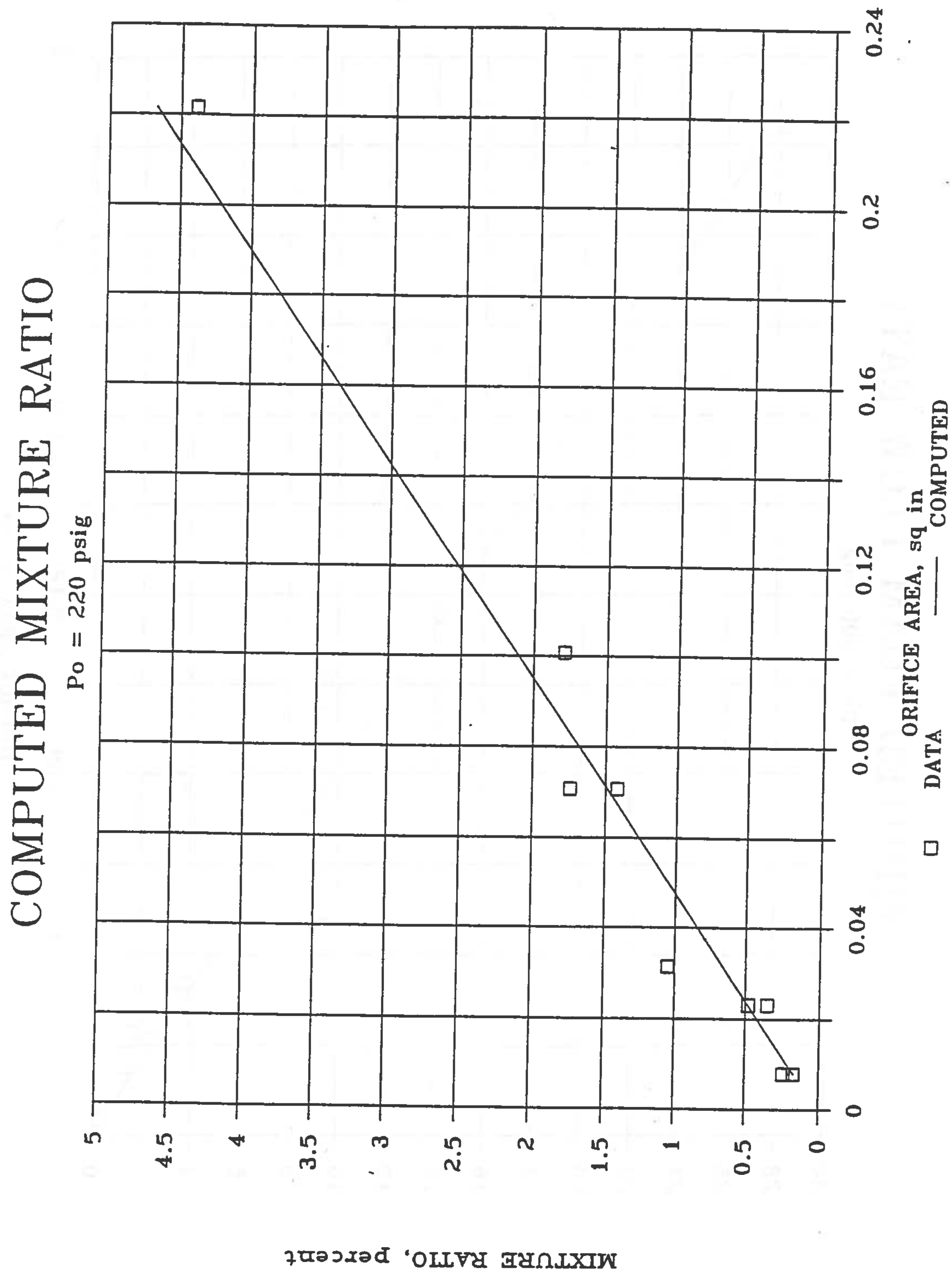

Figure A-27. Computed Mixture Ratio

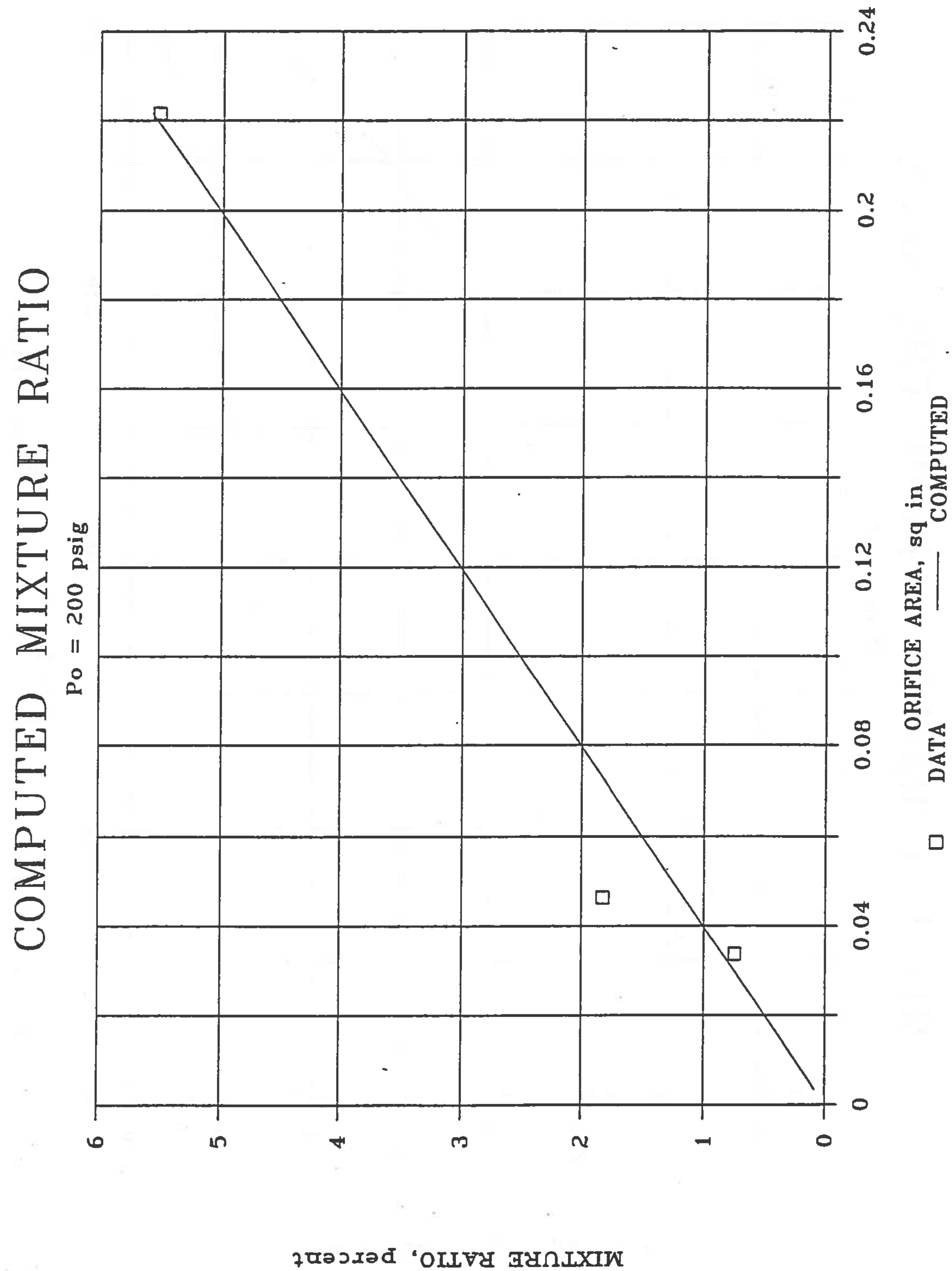

Figure A-28. Computed Mixture Ratio

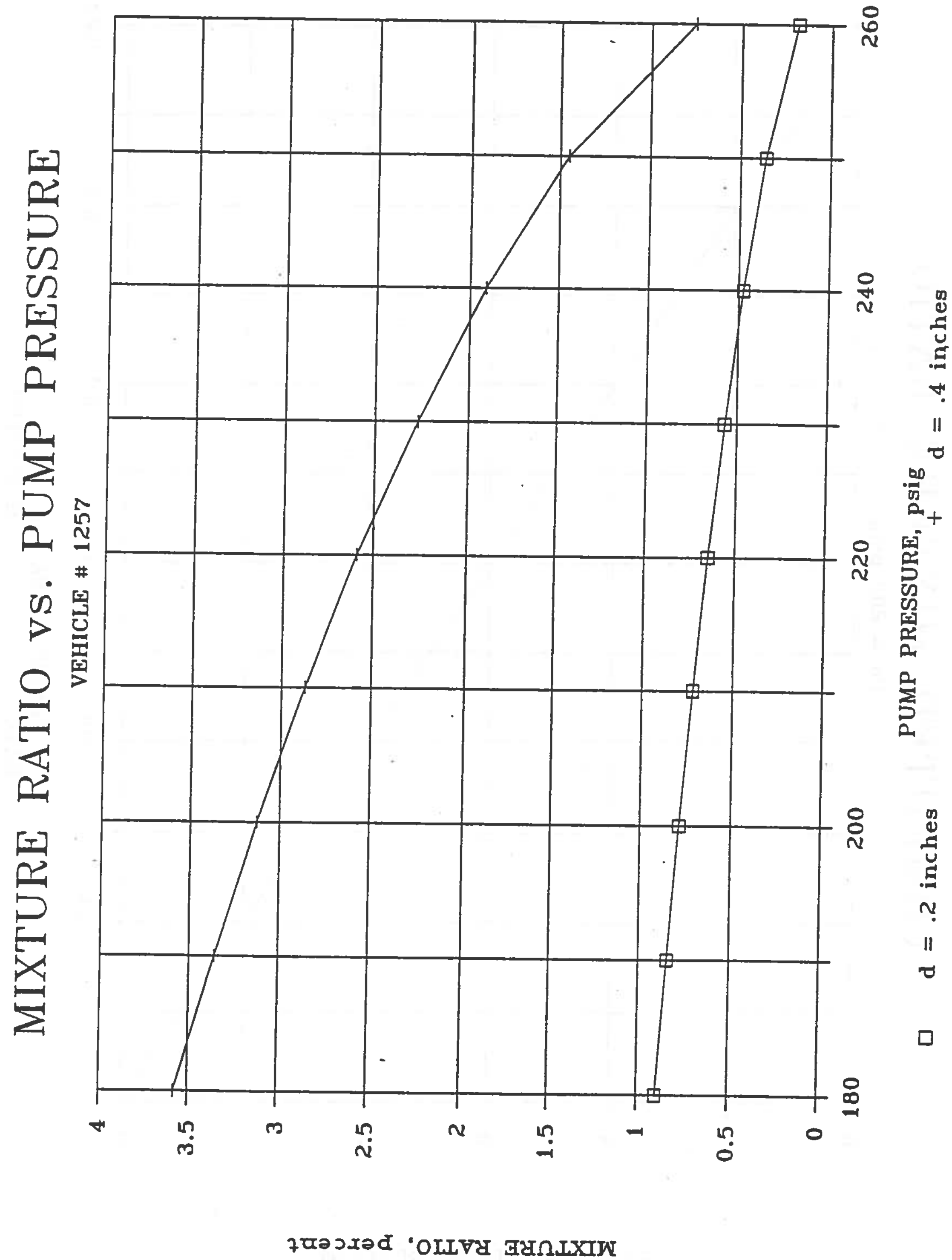

Figure A-29. Mixture Ratio vs. Pump Pressure

C. P-4 CRASH RESCUE VEHICLE

1. Description

A schematic of the P-4 metering system is shown in Figure A-30. Water is pumped through an eductor where it is mixed with foam concentrate and is discharged through one of three different nozzles. The foam concentrate is metered through the valve shown in Figure A-31. Water pressure is monitored and a pilot operated pressure regulator varies the pressure in the foam loop. This is an effective method of controlling the pressure drop across the metering valve in such a way that the amount of concentrate is dispersed in proportion to the water pressure. The roof turret, the bumper turret, and the handline each have their individual metering valve.

2. Test Data

Seven experiments were conducted on two vehicles. Figure A-32 shows the measured mixture ratio as a function of the metering valve setting. The solid line is a result of an analysis of the valve system. Figure A-33 compares data taken from the two vehicles. Note that there is very little scatter in the data. The mixture ratio curves are not coincident; this is due to differences in the metering valves used in the two systems. However, the two systems are very similar, and each system could be used to meter fractional concentrations of AFFF by calibrating each system separately. That is, it appears that each P-4 may require an individual calibration curve.

3. Analysis

Figure A-31a is a schematic of the metering valve. The valve opening is closed as the barrel-like insert is rotated. The cross-hatched section shown in Figure A-31b represents the valve opening. Its a simple matter to compute the valve area as a function of valve settings. This was

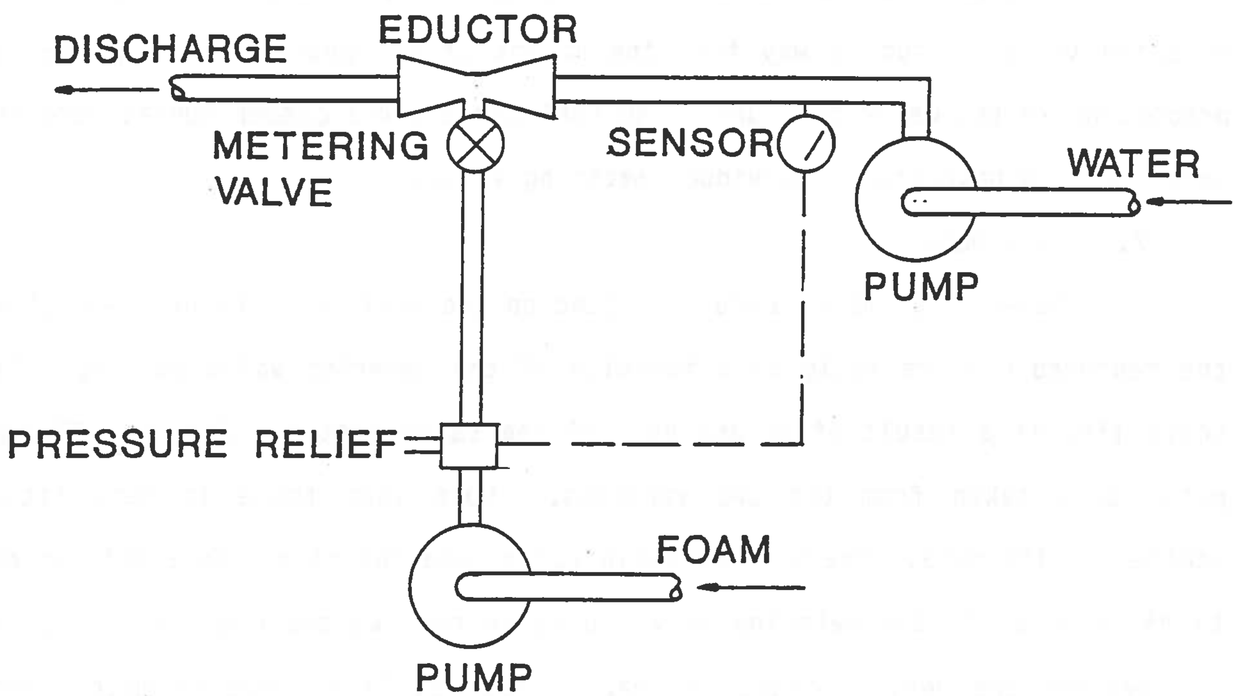

Figure A-30. P-4 Metering System

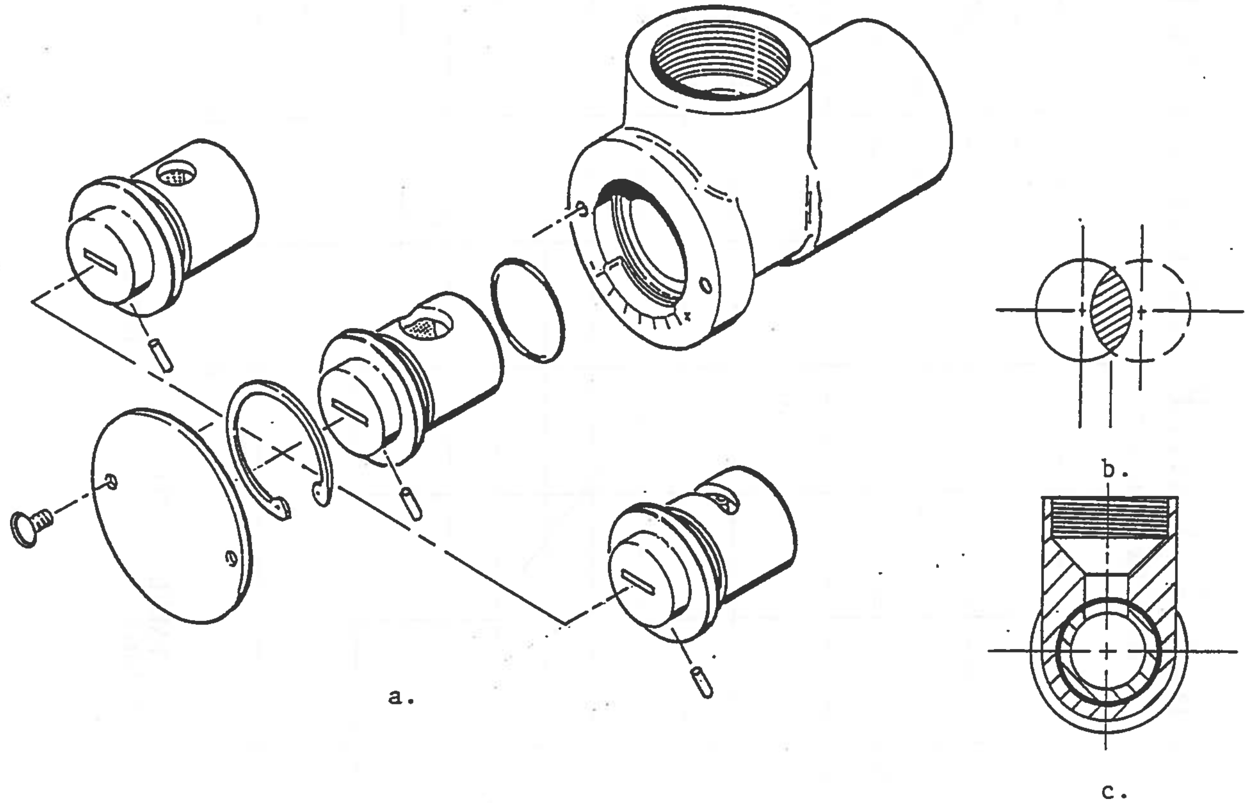

Figure A-31. P-4 Foam Metering Valve

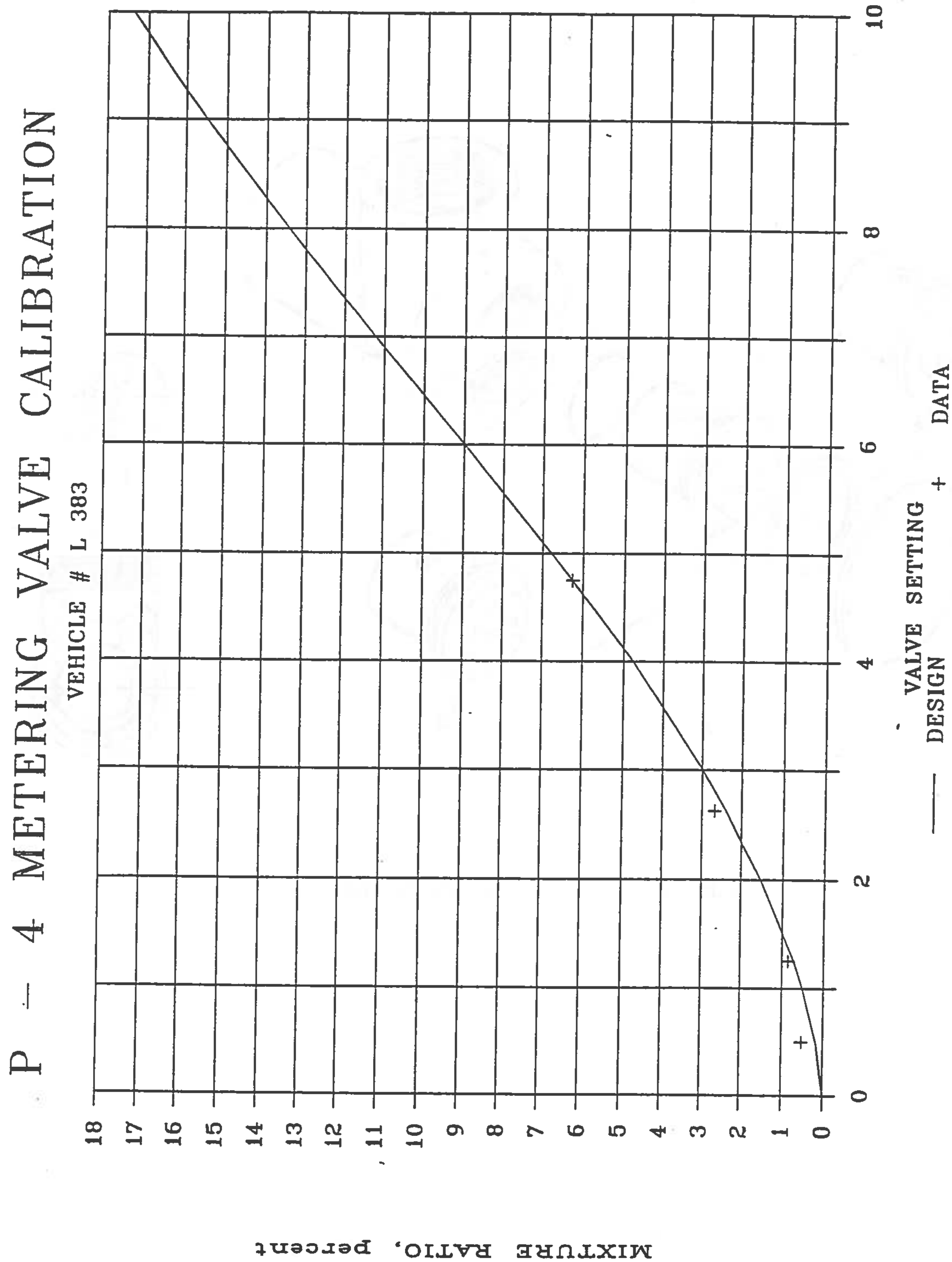

Figure A-32. P-4 Metering Valve Calibration

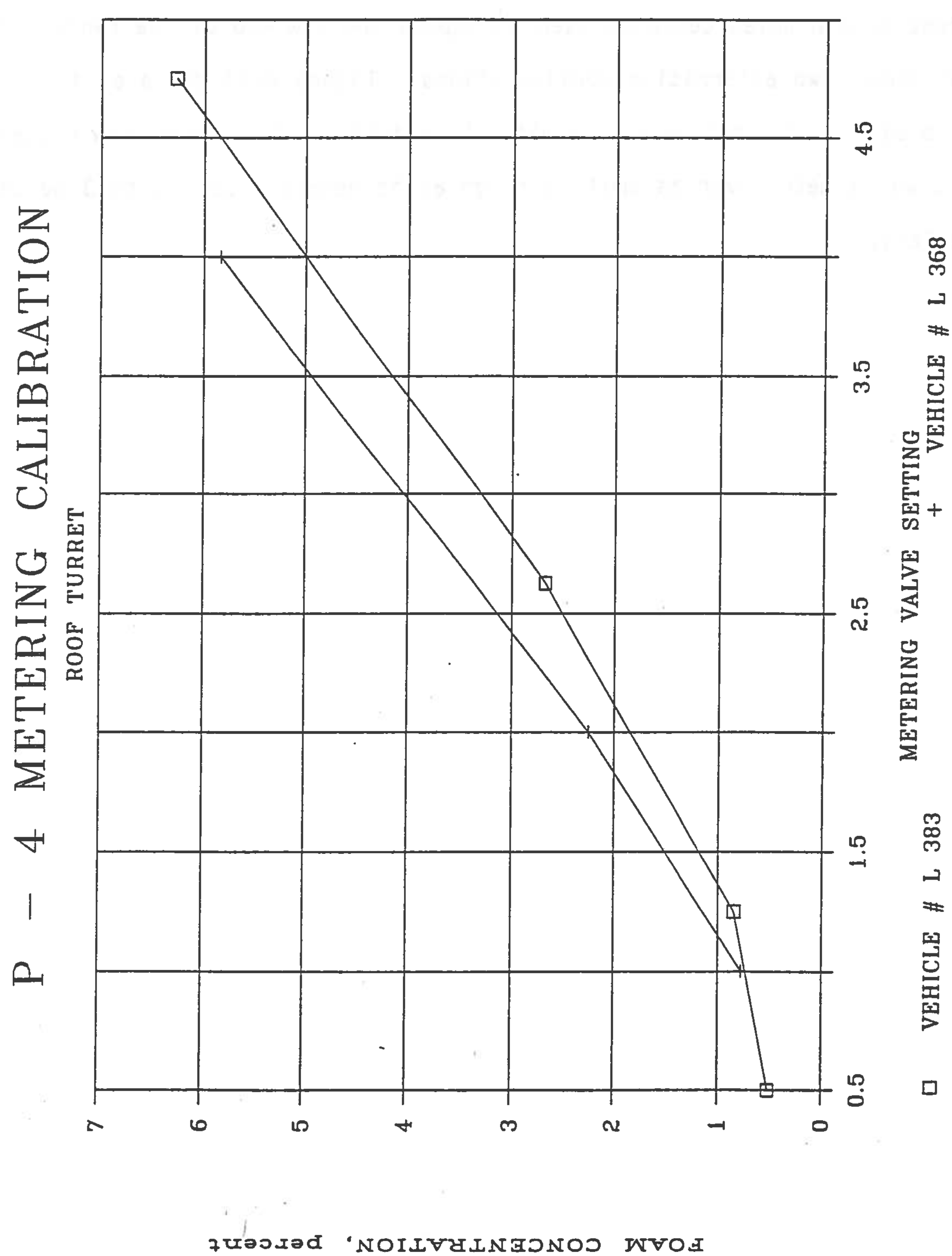

Figure A-33. P-4 Metering Calibration

done, and the solid line in Figure A-32 is the result of this calculation. Agreement with data is reasonable.

The superconcentrates require adjustments over just a small portion of the valve's range. In essence the valve is oversized. An insert with different shaped holes could be used to expand the low end of the range. Figure A-31 shows two alternative configurations. Figure A-34 compares the performance of the new configurations with the existing valve. A narrow rectangular slot would meter over as small a range as is needed (i.e., 0 to 3 percent or smaller).

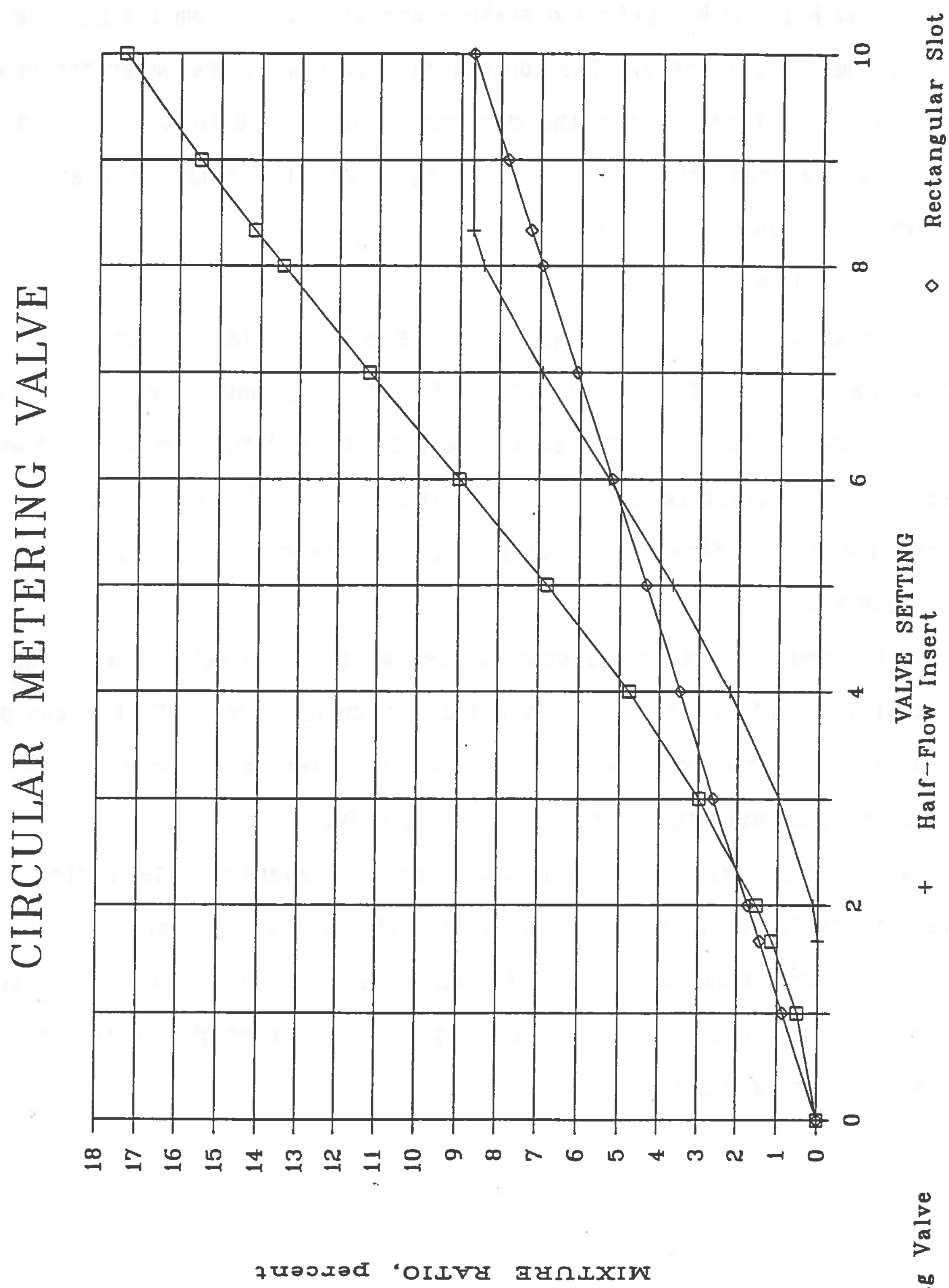

Figure A-34. Circular Metering Valve

D. P-2 CRASH RESCUE VEHICLE

1. Description

The P-2 and P-4 metering systems are similar. Foam concentrate and water are pumped separately. The concentrate mixes with the water through an eductor which is located near the discharge nozzle. Both the P-4 and the newer P-2's use identical circular metering valves to control the amount of concentrate introduced into the system.

2. Test Data

Five tests were run using a single P-2 vehicle. Figure A-35 summarizes the results of these tests. The metering was linear and showed remarkably low scatter. In this series refractometer data were obtained which collaborated the dipstick data. The system appeared to work very well and requires minimal modification to meter fractional percentage foams.

E. RECOMMENDATIONS

The P-2 and P-4 metering systems worked well. Each vehicle will require individual calibration for use with reduced concentration AFFF, but could be used in their existing configurations. Some improvement in performance could be realized by downsizing their foam metering valves.

Analysis was developed which could predict average P-19 performance; however, substantial scatter was present in all the test series. This scatter is in the foam induction loop; the remainder of the system is stable. Consideration should be given to modifying this loop through the introduction of an electronic feedback system.

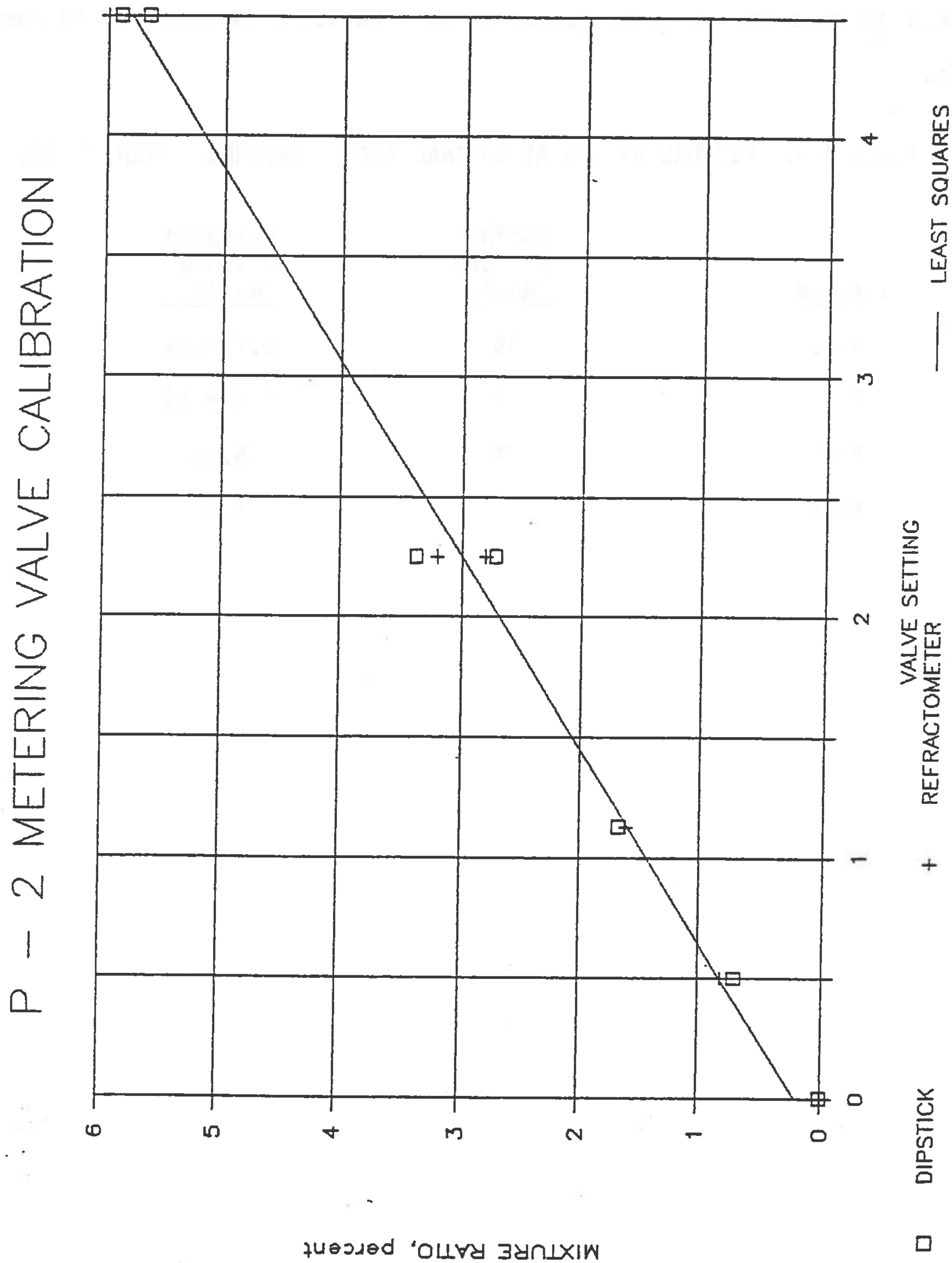

Figure A-35. P-2 Metering Valve Calibration

The metering on every vehicle that we tested was set rich. Table A-5 lists the results for the five vehicles. Substantial savings in foam and increase in capacity could be gained if all the vehicles were set to nominal values.

TABLE A-5. MIXTURE RATIOS AT NOMINAL METER SETTINGS - ROOF TURRET

Vehicle	Nominal Mixture Ratio	Measured Mixture Ratio
P-19	3%	3.7-5.8%
P-4	3%	5.8-6.3%
P-2	3%	5.8%
Mean		5.5%

APPENDIX B

PARTIAL PERCENTAGE AFFF TEST DATA FOR 28 FT^2 FIRE PERFORMANCE TEST

15-Sep-88
301DAT2.WK1

PARTIAL PERCENTAGE AFFF TEST DATA

MANF.	TYPE	WATER	MIXING RATIO	TEST DATE	WIND (MPH)	FOAM TEMP	IGNITION TIME	FOAM START	FIRE EXTINGUISHED	EXTING. TIME (MIN:SEC)	DRY CHEM. TIME	PLACE BURN-BACK PAN	REIGNITION TIME	REMOVE PAN	BURNBACK 25% TIME	F, F, & S IGNIT.	FOAMABILITY TESTS -- CONTNR WT INIT	CONTNR WT FINAL	AGENT WT (gr)	25% DRAINAGE VOLUME	EXPANSION RATIO	25% DRAINAGE TIME
ANSUL	0.75	FRESH	N	29 AUG	CALM	80	09:49:43	09:49:59	09:50:52	53 SEC	N/A	09:51:59	09:53:10	09:53:14	RESEALED	NO	273	456	183	45.75	5.46	2:17
NF	0.75	FRESH	N	15 AUG	CALM	79	09:47:05	09:47:15	09:48:00	45 SEC	N/A	09:49:00	09:53:00	09:53:09	RESEALED	NO	275	468	193	48.25	5.18	3:50
3M	0.75	FRESH	N	26 AUG	CALM	77	09:16:48	09:16:58	09:17:53	55 SEC	N/A	09:19:09	09:20:38	09:20:38	RESEALED	NO	273	462	189	47.25	5.29	2:22
NF	0.75	FRESH	N/2	29 AUG	CALM	81	11:11:07	11:11:17	N/A	N/A	N/A	N/A	N/A	N/A	N/A	NO	273	549	276	69.00	3.62	1:35
3M	0.75	FRESH	N/2	15 AUG	CALM	82	11:30:00	11:30:15	11:31:44	89 SEC	N/A	11:33:30	11:35:00	11:35:05	3:54	NO	272	477	205	51.25	4.88	
ANSUL	0.75	FRESH	N/2	25 AUG	CALM	80	14:52:25	14:52:35	NO EXTING.	NO EXTING.	N/A	N/A	N/A	N/A	N/A	NO	273	516	243	60.75	4.12	1:32
ANSUL	0.75	SEA	5N	22 AUG	10 MPH	81	14:22:13	14:22:22	14:22:59	37 SEC	N/A	14:25:32	14:28:04	14:28:10	3:14	NO	273	396	123	30.75	8.13	3:00
NF	0.75	SEA	5N	26 AUG	CALM	78	11:20:03	11:20:13	11:20:47	34 SEC	N/A	11:22:21	11:25:02	11:25:09	4:50	NO	273	401	128	32.00	7.81	3:48
3M	0.75	SEA	5N	23 AUG	6 MPH	79	11:59:13	11:59:23	12:00:06	43 SEC	N/A	12:01:32	12:05:09	12:05:14	5:44	NO	273	373	100	25.00	10.00	3:00
ANSUL	0.75	SEA	N	24 AUG	10 MPH	78	10:03:32	10:03:42	10:04:52	70 SEC	10:05:40	10:07:14	10:08:30	10:08:33	RESEALED	NO	273	475	202	50.50	4.95	2:00
3M	0.75	SEA	N	24 AUG	9 MPH	78	13:52:54	13:53:04	13:53:48	44 SEC	13:55:14	13:56:06	13:58:25	13:58:30	RESEALED	NO	273	460	187	46.75	5.35	2:13
NF	0.75	SEA	N	26 AUG	CALM	78	10:35:37	10:35:47	10:36:27	40 SEC	10:37:53	10:38:32	10:40:52	10:41:00	6:41	NO	273	465	192	48.00	5.21	2:24
NF	0.75	SEA	N/2	26 AUG	CALM	80	14:40:40	14:40:50	14:41:42	62 SEC	N/A	14:42:49	14:44:15	14:44:20	RESEALED	NO	273	601	328	82.00	3.05	1:15
ANSUL	0.75	SEA	N/2	25 AUG	CALM	76	13:32:54	13:33:04	NO EXTING.	NO EXTING.	N/A	N/A	N/A	N/A	N/A	YES	273	570	297	74.25	3.37	1:30
3M	0.75	SEA	N/2	26 AUG	CALM	80	13:24:40	13:24:50	NO EXTING.	NO EXTING.	N/A	N/A	N/A	N/A	N/A	YES	273	588	315	78.75	3.17	1:09
3M	1.00	FRESH	N	30 AUG	CALM	79	14:11:08	14:11:18	14:11:57	39 SEC	N/A	14:13:12	14:15:09	14:15:12	RESEALED	NO	273	403	130	32.50	7.69	2:49
ANSUL	1.00	FRESH	N	24 AUG	9 MPH	80	10:45:06	10:45:16	10:46:00	44 SEC	N/A	10:47:38	10:49:45	10:50:00	RESEALED	NO	273	433	160	40.00	6.25	2:15
NF	1.00	FRESH	N	15 AUG	5-10 MP	82	14:01:00	14:01:16	14:01:45	29 SEC	N/A	14:03:14	14:06:05	14:06:13	4:11	NO	272	411	139	34.75	7.19	2:30
3M	1.00	FRESH	N/2	22 AUG	CALM	82	09:31:07	09:31:17		NO EXTING.	N/A	N/A	N/A	N/A	N/A	NO	273	466	193	48.25	5.18	1:48
ANSUL	1.00	FRESH	N/2	30 AUG	CALM	80	15:10:57	15:11:07	NO EXTING.	NO EXTING.	N/A	N/A	N/A	N/A	N/A	NO	273	484	211	52.75	4.74	1:45
NF	1.00	FRESH	N/2	22 AUG	CALM	80	11:47:39	11:47:49	11:48:59	70 SEC	N/A	11:49:59	11:51:04	11:52:34	RESEALED	NO	273	555	282	70.50	3.55	0:90
NF	1.00	SEA	5N	24 AUG	CALM	81	09:06:47	09:06:57	09:07:35	38 SEC	N/A	09:09:07	09:11:37	09:11:45	4:44	NO	273	408	135	33.75	7.41	4:11
3M	1.00	SEA	5N	23 AUG	CALM	79	09:41:30	09:41:40	09:42:23	43 SEC	N/A	09:44:30	09:46:00	09:46:05	5:07	NO	273	371	98	24.50	10.20	3:00
ANSUL	1.00	SEA	5N	29 AUG	CALM	82	13:56:55	13:56:05	13:57:50	45 SEC	N/A	13:59:01	14:01:00	14:01:10	4:09	NO	273	390	117	29.25	8.55	3:30
NF	1.00	SEA	N	25 AUG	CALM	81	14:08:21	14:08:31	14:09:28	57 SEC	14:10:46	14:11:28	14:13:23	14:13:29	6:40	NO	273	430	157	39.25	6.37	2:41
ANSUL	1.00	SEA	N	18 AUG	5-8 MPH	81	14:26:01	14:26:12	14:26:55	43 SEC	14:28:20	14:28:30	14:31:16	14:31:32	RESEALED	NO	273	455	182	45.50	5.49	2:17
3M	1.00	SEA	N	30 AUG	CALM	78	12:11:36	12:11:46	12:12:39	53 SEC	12:13:39	12:14:08	12:16:54	12:17:00	RESEALED	NO	273	468	195	48.75	5.13	2:11
NF	1.00	SEA	N/2	26 AUG	CALM	80	14:01:59	14:02:09	14:02:51	42 SEC	N/A	14:04:12	14:05:42	14:06:00	RESEALED	NO	273	516	243	60.75	4.12	1:50
ANSUL	1.00	SEA	N/2	29 AUG	CALM	80	10:19:48	10:19:58	10:21:06	68 SEC	N/A	10:22:29	10:23:27	10:23:30	RESEALED	NO	273	476	203	50.75	4.93	2:13
3M	1.00	SEA	N/2	30 AUG	CALM	79	14:39:43	14:39:53	NO EXTING.	NO EXTING.	N/A	N/A	N/A	N/A	N/A	NO	273	528	255	63.75	3.92	1:28
ANSULITE	3.00	FRESH	N	25 AUG	5 MPH	76	10:38:04	10:38:14	10:39:04	50 SEC	N/A	10:41:37	10:44:30	10:44:40	10:04:10	YES	272	368	96	24.00	10.42	0:48
ANSULITE	3.00	FRESH	N	26 JUL	5 MPH	74	09:31:45	09:31:55	09:33:02	67 SEC	N/A	EXTINGUISHMENT ONLY										
ANSULITE	3.00	FRESH	N	26 JUL	6 MPH	76	11:17:02	11:17:12	11:18:09	57 SEC	N/A	EXTINGUISHMENT ONLY										
ANSULITE	3.00	FRESH	N	25 JUL	5 MPH	76	11:43:26	11:43:36	11:44:11	36.27 SEC	N/A	EXTINGUISHMENT ONLY										
ANSULITE	3.00	FRESH	N	25 JUL	7 MPH	76	14:03:00	14:03:10	14:04:14	74 SEC	N/A	EXTINGUISHMENT ONLY										
ANSULITE	3.00	FRESH	N	25 JUL	5 MPH	74	14:37:00	14:37:12	14:37:47	35 SEC	N/A	EXTINGUISHMENT ONLY										
3M	6.00	FRESH	N	14 SEP/1	6 MPH	78	09:41:58	09:42:58	09:42:58	50 SEC	N/A	09:44:00	09:46:00	09:46:05	RESEALED	N/A	273	418	145	36.25	6.90	3:14
3M	6.00	FRESH	N	14 SEP/6	6-9 MPH	80	14:09:50	14:10:00	14:11:13	73 SEC	N/A	14:12:15	14:14:34	14:14:40	3.35	N/A	273	411	138	34.50	7.25	3:15
3M	6.00	FRESH	N	14 SEP/4	5-8 MPH	78	13:09:05	13:09:15	13:10:11	56 SEC	N/A	13:11:15	13:13:27	13:13:30	RESEALED	N/A	273	407	134	33.50	7.46	3:19
3M	6.00	FRESH	N	14 SEP/5	6-9 MPH	80	13:40:16	13:40:29	13:40:02	33 SEC	N/A	13:42:19	13:44:11	13:44:14	RESEALED	N/A	273	416	143	35.75	6.99	3:23
3M	6.00	FRESH	N	14 SEP/2	6-9 MPH	78	10:19:43	10:19:53	10:21:14	81 SEC	N/A	10:21:59	10:23:12	10:23:16	RESEALED	N/A	273	408	135	33.75	7.41	3:30
3M	6.00	FRESH	N	14 SEP/3	5-9 MPH	82	10:52:25	10:52:35	10:53:47	72 SEC	N/A	10:54:58	10:56:46	10:56:54	2:31	N/A	273	405	132	33.00	7.58	3:13
3% STATIONARY NOZZLE TEST																						
ANSUL	3.00	FRESH	N	14 SEP	6-9 MPH	78	14:52:08	14:52:18	14:54:08	120 SEC	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
COMPATIBILITY T*******																						
NF/3M	0.75	FRESH	N	23 AUG	CALM	78	11:17:36	11:17:46	11:18:58	72 SEC	N/A	11:20:00	11:21:30	11:31:34	RESEALED	NO	273	460	187	46.75	5.35	2:21
ANSUL/3M	0.75	FRESH	N	26 AUG	CALM	80	09:49:30	09:49:40	09:50:34	54 SEC	N/A	09:51:44	09:53:30	09:53:40	RESEALED	NO	273	466	193	48.25	5.18	1:37
ANSUL/NF	0.75	FRESH	N	25 AUG	CALM	82	15:21:52	15:22:02	15:22:56	54 SEC	N/A	15:24:03	15:27:10	15:27:16	RESEALED	NO	273	446	173	43.25	5.78	1:43
ANSUL/3M	0.75	SEA	N	29 AUG	CALM	79	12:01:12	12:01:22	12:02:11	49 SEC	12:03:30	12:04:02	12:05:27	N/A	RESEALED	NO	273	511	238	59.50	4.20	2:00
ANSUL/NF	0.75	SEA	N	30 AUG	CALM	78	11:23:18	11:23:28	11:24:18	50 SEC	11:25:28	11:25:53	11:28:23	11:28:29	7:41	NO	273	483	210	52.50	4.76	2:10
NF/3M	0.75	SEA	N	23 AUG	CALM	81	10:33:23	10:33:33	10:34:30	57 SEC	10:35:00	10:36:24	10:38:33	10:38:40	5:18	NO	273	434	161	40.25	6.21	2:04
NF/3M	1.00	FRESH	N	23 AUG	7 MPH	82	14:07:50	14:08:00	14:08:33	33 SEC	N/A	14:10:10	14:13:19	14:13:29	RESEALED	NO	273	407	134	33.50	7.46	3:03
ANSUL/3M	1.00	FRESH	N	30 AUG	CALM	79	10:37:58	10:38:08	10:38:48	40 SEC	N/A	10:40:03	10:41:28	10:41:35	RESEALED	NO	273	441	168	42.00	5.95	2:50
ANSUL/NF	1.00	FRESH	N	26 AUG	CALM	82	08:36:40	08:36:50	08:37:23	33 SEC	N/A	08:39:00	08:41:16	08:41:21	5:34	NO	273	415	142	35.50	7.04	2:30
NF/3M	1.00	SEA	N	29 AUG	CALM	79	15:27:06	15:27:16	15:27:50	34 SEC	15:29:30	15:29:50	15:32:15	15:32:20	11:25	NO	273	495	222	55.50	4.50	1:39
ANSUL/3M	1.00	SEA	N	23 AUG	CALM	82	14:50:40	14:50:50	14:51:32	42 SEC	14:52:57	14:53:31	14:55:57	14:56:05	10:06	NO	273	450	177	44.25	5.65	2:13
ANSUL/NF	1.00	SEA	N	29 AUG	CALM	79	14:39:27	14:39:37	14:40:12	35 SEC	14:41:54	14:42:16	14:45:09	14:45:12	7:54	NO	273	456	183	45.75	5.46	2:30

APPENDIX B

PARTIAL PERCENTAGE AFFF TEST DATA
FOR 28 FT² FIRE PERFORMANCE TEST

APPENDIX C

PARTIAL PERCENTAGE AFFF TEST DATA FOR 50 FT^2 FIRE PERFORMANCE TEST

APPENDIX C

PARTIAL PERCENTAGE AFFF TEST DATA FOR 50 FT^2 FIRE PERFORMANCE TEST

MANUFACTURER	TYPE	WATER	MIXING RATIO	TEST DATE	WIND (MPH)	FOAM TEMP.	IGNITION TIME	FOAM START	FIRE EXT.	EXT. TIME (SEC.)	PLACE BURN BACK PAN	REIGNITION TIME	REMOVE PAN	BURN BACK 25% TIME	40 SECOND SUMMATION
NATIONAL	1%	SEA	N	08/31/88	8-10 MPH	77	09.14.53	09.15.03	09.16.20	77	09.16.57	09.18.18	09.18.22	4.41	180
ANSUL	1%	SEA	N	08/31/88	6-8 MPH	77	10.27.16	10.27.26	No Ext.	No Ext.	N/A	N/A	N/A	N/A	220
3M	1%	SEA	N	08/31/88	CALM	77	02.05.34	02.05.44	02.06.47	63	02.07.39	02.08.20	02.08.22	Resealed	220
NATIONAL	3/4%	SEA	N	08/31/88	5-8 MPH	77	11.07.01	11.07.11	11.08.37	86	11.09.13	11.10.33	11.10.36	4.26	215
ANSUL	3/4%	SEA	N	08/31/88	CALM	77	12.08.40	12.08.50	No Ext.	No Ext.	N/A	N/A	N/A	N/A	105
3M	3/4%	SEA	N	08/31/88	CALM	78	02.40.43	02.40.53	02.42.19	86	02.42.39	02.44.19	02.44.23	Resealed	180

APPENDIX D

GENERAL CORROSION TEST

RESULTS

GENERAL CORROSION STUDY

AGENT	SPECIMEN		START WEIGHT GRAMS	END WEIGHT GRAMS	RESULTS
Ansulite 1%	Steel UNS G10100	01	11.74	11.74	No Weight Change Slight Rust on One Surface, Top Edge.
		02	11.78	11.79	No Significant Weight Change Slight Rust on One Surface, Top Edge.
		03	11.79	11.80	No Significant Weight Change Rust on Top and Bottom Edge.
		04	11.42	11.41	No Significant Weight Change Rust on Top and Bottom Edge.
		05	11.62	11.61	No Significant Weight Change Slight Rust on Bottom Edge.

GENERAL CORROSION STUDY

AGENT	SPECIMEN		START WEIGHT GRAMS	END WEIGHT GRAMS	RESULTS
Ansulite 1%	Copper-Nickel Stainless UNS C70600	01	12.49	12.41	Failed, average weight loss .09 grams
		02	12.60	12.51	Failed, average weight loss .09 grams
		03	12.62	12.51	Failed, average weight loss .09 grams
		04	12.67	12.58	Failed, average weight loss .09 grams
		05	12.64	12.56	Failed, average weight loss .09 grams

NOTE: Concentrate clear, black tarnish on all surfaces.

GENERAL CORROSION STUDY

AGENT	SPECIMEN		START WEIGHT GRAMS	END WEIGHT GRAMS	RESULTS
Ansulite 1%	Nickel-Copper Stainless UNS N04400	01	12.41	12.41	No Weight Change
		02	12.55	12.54	No Significant Weight Change
		03	12.40	12.40	No Weight Change
		04	12.59	12.59	No Weight Change
		05	12.21	12.22	No Significant Weight Change

NOTE: Specimens 01 through 05 no corrosion, all surfaces clear, concentrate clear.

AGENT	SPECIMEN		START WEIGHT GRAMS	END WEIGHT GRAMS	RESULTS
Ansulite 1%	Bronze UNS C90500	01	38.76	38.73	No Significant Weight Change
		02	39.57	39.51	No Significant Weight Change
		03	39.86	39.81	No Significant Weight Change
		04	40.69	40.63	No Significant Weight Change
		05	37.81	37.73	No Significant Weight Change

NOTE: Specimens 01 through 05, black tarnish all surfaces, concentrate dark blue.

GENERAL CORROSION STUDY

AGENT	SPECIMEN		START WEIGHT GRAMS	END WEIGHT GRAMS	RESULTS
Ansul 3/4%	Steel UNS G10100	11	11.60	11.57	No Significant Weight Change
		12	11.73	11.67	No Significant Weight Change
		13	11.78	11.72	No Significant Weight Change
		14	11.77	11.74	No Significant Weight Change
		15	11.57	11.53	No Significant Weight Change

NOTE: Specimens 11 through 15, rust on 25% flat surface and edges, concentrate rusty color.

AGENT	SPECIMEN		START WEIGHT GRAMS	END WEIGHT GRAMS	RESULTS
Ansul 3/4%	Copper-Nickel Stainless UNS C70600	11	12.52	12.40	Failed, average weight loss .11 grams
		12	13.07	12.97	Failed, average weight loss .11 grams
		13	12.47	12.36	Failed, average weight loss .11 grams
		14	12.39	12.29	Failed, average weight loss .11 grams
		15	12.61	12.49	Failed, average weight loss .11 grams

NOTE: Specimens 11 through 15, black corrosion all 6 sides 90%, concentrate medium blue.

GENERAL CORROSION STUDY

AGENT	SPECIMEN		START WEIGHT GRAMS	END WEIGHT GRAMS	RESULTS
Ansul 3/4%	Nickel-Copper Stainless UNS N04400	11	12.43	12.43	No Weight Change
		12	12.45	12.45	No Weight Change
		13	12.01	12.01	No Weight Change
		14	12.26	12.26	No Weight Change
		15	12.39	12.39	No Weight Change

NOTE: Specimens 11 through 15, no corrosion, concentrate medium blue.

AGENT	SPECIMEN		START WEIGHT GRAMS	END WEIGHT GRAMS	RESULTS
Ansul 3/4%	Bronze UNS C90500	11	35.51	35.43	No Significant Weight Change
		12	39.90	39.81	No Significant Weight Change
		13	40.21	40.12	No Significant Weight Change
		14	36.52	36.42	No Significant Weight Change
		15	37.15	37.05	No Significant Weight Change

NOTE: Specimens 11 through 15, discoloration, concentrate medium blue.

GENERAL CORROSION STUDY

AGENT	SPECIMEN		START WEIGHT GRAMS	END WEIGHT GRAMS	RESULTS
3M 1%	Steel UNS G10100	06	11.73	11.77	No Significant Weight Change Concentrate Clear
		07	11.57	11.60	No Significant Weight Change Concentrate Clear
		08	11.62	11.65	No Significant Weight Change Concentrate Clear
		09	11.53	11.58	No Significant Weight Change Concentrate Clear
		10	11.71	11.76	No Significant Weight Change

NOTE: Specimens 06 through 10, rust sediments in bottom of containers, 75% rust build up on all surfaces.

AGENT	SPECIMEN		START WEIGHT GRAMS	END WEIGHT GRAMS	RESULTS
3M 1%	Copper-Nickel Stainless UNS C70600	06	12.36	12.35	No Significant Weight Change
		07	12.58	12.58	No Weight Change
		08	12.30	12.30	No Weight Change
		09	12.75	12.75	No Weight Change
		10	12.45	12.45	No Weight Change

NOTE: Specimens 06 through 10, 75% heavy build up of green and yellow corrosion front and back, heavy sediment in bottom of containers, concentrate clear.

GENERAL CORROSION STUDY

AGENT	SPECIMEN		START WEIGHT GRAMS	END WEIGHT GRAMS	RESULTS
3M 1%	Nickel-Copper Stainless UNS N04400	06	12.55	12.54	No Significant Weight Change
		07	12.54	12.54	No Weight Change
		08	12.30	12.30	No Weight Change
		09	12.51	12.51	No Weight Change
		10	12.23	12.23	No Weight Change

NOTE: Concentrate clear, Specimens 06 through 10, no corrosion.

AGENT	SPECIMEN		START WEIGHT GRAMS	END WEIGHT GRAMS	RESULTS
3M 1%	Bronze UNS C90500	06	39.44	39.39	No Significant Weight Change
		07	37.70	37.67	No Significant Weight Change
		08	37.93	37.87	No Significant Weight Change
		09	37.59	37.57	No Significant Weight Change
		10	40.09	40.20	No Significant Weight Change

NOTE: Some particles of green sediment in bottom of containers, irregular green/blue colored corrosion on Specimens 06 through 10.

GENERAL CORROSION STUDY

AGENT	SPECIMEN		START WEIGHT GRAMS	END WEIGHT GRAMS	RESULTS
National 1%	Steel UNS G10100	16	11.79	11.67	Failed, average weight loss .124 grams
		17	11.61	11.51	Failed, average weight loss .124 grams
		18	11.55	11.42	Failed, average weight loss .124 grams
		19	11.67	11.54	Failed, average weight loss .124 grams
		20	11.71	11.57	Failed, average weight loss .124 grams

NOTE: Specimens 16 through 20, black tarnish covering all surfaces. Heavy sediment in bottom of containers.

AGENT	SPECIMEN		START WEIGHT GRAMS	END WEIGHT GRAMS	RESULTS
National 1%	Copper-Nickel Stainless UNS C70600	16	12.66	12.65	No Significant Weight Change
		17	12.61	12.61	No Significant Weight Change
		18	12.78	12.77	No Significant Weight Change
		19	12.80	12.79	No Significant Weight Change
		20	12.50	12.49	No Significant Weight Change

NOTE: Specimens 16 through 20, light tarnish corrosion spots on both sides. Heavy sediment in bottom of containers.

GENERAL CORROSION STUDY

AGENT	SPECIMEN		START WEIGHT GRAMS	END WEIGHT GRAMS	RESULTS
National 1%	Nickel-Copper Stainless UNS N04400	16	12.54	12.53	No Significant Weight Change Concentrate Clear
		17	12.30	12.29	No Significant Weight Change Concentrate Clear
		18	12.37	12.36	No Significant Weight Change Concentrate Clear
		19	12.36	12.35	No Significant Weight Change Concentrate Clear
		20	12.48	12.47	No Significant Weight Change

NOTE: Specimens 16 through 20, discoloration, light sediment bottom of containers.

AGENT	SPECIMEN		START WEIGHT GRAMS	END WEIGHT GRAMS	RESULTS
National 1%	Bronze UNS C90500	16	35.64	35.64	No Weight Change
		17	35.69	35.69	No Weight Change
		18	36.51	36.52	No Significant Weight Change
		19	39.62	39.62	No Weight Change
		20	38.38	38.39	No Significant Weight Change

NOTE: Specimens 16 through 20, green corrosion on bottom surfaces, light sediment in bottom of container.

GENERAL CORROSION STUDY

AGENT	SPECIMEN		START WEIGHT GRAMS	END WEIGHT GRAMS	RESULTS
Nat'l 3/4%	Steel UNS G10100	21	11.77	11.66	Failed, average weight loss .132 grams
		22	11.73	11.60	Failed, average weight loss .132 grams
		23	11.74	11.60	Failed, average weight loss .132 grams
		24	11.79	11.65	Failed, average weight loss .132 grams
		25	11.83	11.69	Failed, average weight loss .132 grams

NOTE: Concentrate clear, heavy sediment in bottom of containers, Specimens 21 through 25, heavy dark tarnish on all surfaces.

AGENT	SPECIMEN		START WEIGHT GRAMS	END WEIGHT GRAMS	RESULTS
Nat'l 3/4%	Copper-Nickel Stainless UNS C70600	21	12.61	12.61	No Weight Change
		22	12.91	12.90	No Significant Weight Change
		23	12.57	12.55	No Significant Weight Change
		24	12.76	12.75	No Significant Weight Change
		25	12.37	12.37	No Weight Change

NOTE: Specimens 21 through 25, green/black corrosion spots on front and back, concentrate clear, light sediment in bottom of container.

GENERAL CORROSION STUDY

AGENT	SPECIMEN		START WEIGHT GRAMS	END WEIGHT GRAMS	RESULTS
Nat'l 3/4%	Nickel-Copper Stainless UNS N04400	21	12.09	12.09	No Weight Change
		22	12.36	12.37	No Significant Weight Change
		23	12.39	12.39	No Weight Change
		24	12.35	12.35	No Weight Change
		25	12.34	12.33	No Significant Weight Change

NOTE: Specimens 21 through 25, light discoloration, concentrate clear, light sediment bottom of container.

AGENT	SPECIMEN		START WEIGHT GRAMS	END WEIGHT GRAMS	RESULTS
Nat'l 3/4%	Bronze UNS C90500	21	38.07	38.08	No Significant Weight Change
		22	39.29	39.30	No Significant Weight Change
		23	35.93	35.94	No Significant Weight Change
		24	39.93	39.94	No Significant Weight Change
		25	40.34	40.35	No Significant Weight Change

NOTE: Specimens 21 through 25, green corrosion spots front and bottom edge, concentrate clear, light sediment in bottom of containers.

APPENDIX E

LOCALIZED CORROSION STUDY

LOCALIZED CORROSION STUDY

AGENT	SPECIMEN		START WEIGHT GRAMS	END WEIGHT GRAMS	RESULTS
Ansulite 1%	S30400 Stainless Steel CRES	01	10.56	10.56	No Weight Change
		02	10.59	10.59	No Significant Weight Change
		03	10.80	10.80	No Weight Change
		04	10.62	10.62	No Weight Change
		05	10.36	10.37	No Significant Weight Change
		06	10.52	10.52	No Weight Change
		07	10.60	10.61	No Significant Weight Change
		08	10.25	10.26	No Significant Weight Change
		09	10.60	10.61	No Significant Weight Change
		10	10.53	10.54	No Significant Weight Change

NOTE: All specimens clear, no pits or corrosion apparent, concentrate clear.

LOCALIZED CORROSION STUDY

AGENT	SPECIMEN		START WEIGHT GRAMS	END WEIGHT GRAMS	RESULTS
3M 1%	S30400 Stainless Steel CRES	11	10.65	10.65	No Weight Change
		12	10.51	10.52	No Significant Weight Change
		13	10.68	10.68	No Weight Change
		14	10.64	10.64	No Weight Change
		15	10.52	10.52	No Weight Change
		16	10.52	10.53	No Significant Weight Change
		17	10.63	10.64	No Significant Weight Change
		18	10.49	10.49	No Weight Change
		19	10.63	10.63	No Weight Change
		20	10.78	10.78	No Weight Change

NOTE: Concentrate clear, no sediment, slight strains under rubberbands on front and back of all specimens. No pits or corrosion.

LOCALIZED CORROSION STUDY

AGENT	SPECIMEN		START WEIGHT GRAMS	END WEIGHT GRAMS	RESULTS
Ansul 3/4%	S30400 Stainless Steel CRES	21	10.52	10.53	No Significant Weight Change
		22	10.33	10.33	No Weight Change
		23	10.61	10.62	No Significant Weight Change
		24	10.25	10.25	No Weight Change
		25	10.62	10.64	No Significant Weight Change
		26	10.52	10.52	No Weight Change
		27	10.63	10.63	No Weight Change
		28	10.59	10.59	No Weight Change
		29	10.38	10.38	No Weight Change
		30	10.26	10.26	No Weight Change

NOTE: All specimens clear, no corrosion or pitting, concentrate clear, no sediment.

LOCALIZED CORROSION STUDY

AGENT	SPECIMEN		START WEIGHT GRAMS	END WEIGHT GRAMS	RESULTS
National 1%	S30400 Stainless Steel CRES	31	10.60	10.60	No Weight Change
		32	10.66	10.65	No Significant Weight Change
		33	10.50	10.51	No Significant Weight Change
		34	10.40	10.40	No Weight Change
		35	10.63	10.64	No Significant Weight Change
		36	10.71	10.71	No Weight Change
		37	10.63	10.63	No Weight Change
		38	10.59	10.59	No Weight Change
		39	10.57	10.57	No Weight Change
		40	10.38	10.38	No Weight Change

NOTE: All specimens clear of corrosion/pitting, concentrate clear of sediment.

LOCALIZED CORROSION STUDY

AGENT	SPECIMEN		START WEIGHT GRAMS	END WEIGHT GRAMS	RESULTS
Nat'l 3/4%	S30400 Stainless Steel CRES	41	10.51	10.51	No Weight Change
		42	10.42	10.42	No Weight Change
		43	10.49	10.49	No Weight Change
		44	10.59	10.59	No Weight Change
		45	10.54	10.54	No Weight Change
		46	10.37	10.37	No Weight Change
		47	10.21	10.21	No Weight Change
		48	10.46	10.46	No Weight Change
		49	10.70	10.70	No Weight Change
		50	10.24	10.24	No Weight Change

NOTE: All specimens clear, no pits or corrosion.